SEMANTIC AWARENESS OF FOUNDATION-YEAR AND FIRST-YEAR PHYSICS LEARNERS AT THE UNIVERSITY OF PRETORIA

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that it has not been submitted, either in its entirety or in part, at any university for a degree.

ABSTRACT

This study investigates and measures the correlation (or "gap") between the perceptions held by learners and lecturers of learners' knowledge of selected Physics terms and the accuracy of such perceptions.

Several theorists have pointed to the differences between meaning(s) of vocabulary used by specialists and vocabulary used by lay people. One of the primary sources of confusion is that the scientific terminology and lay words are identical in spelling and pronunciation but fundamentally different in meaning. With reference to a variety of social and educational researchers, this study endorses the view that, in a Physics classroom at higher education level, the lecturer and the learners occupy two separate worlds – each with unique (and potentially exclusive) terms of reference. The success of any Physics tuition in such a setting rests upon the ability of learners and lecturers to bridge the comprehension "gap" between the two worlds.

Three related but independent sub-disciplines were consulted in studying this phenomenon: educational theory (specifically Science education); semantics and communication theory. Principles from each discipline are referred to in order to show that successful Science education at the foundation and first-year level of higher education could be as much a matter of communication as is it of science.

The study propounds that communication in a setting where vocabulary crucial to the subject is not understood adequately by the learners, often fails. On the basis of the literature review, a pilot study was done using a modified version of Jacobs's 1989 questionnaire. The questionnaire required the respondents to indicate their confidence in their vocabulary knowledge, and then tested their actual vocabulary knowledge.

As the main study, a modified formal test was administered to 216 learners and four lecturers. One group of learners (numbering 100) was registered in a foundation year programme, another group (numbering 59) was registered in an extended programme, while the third group (numbering 57) was registered in a BSc course in the Faculty of Agricultural and Natural Sciences at the University of Pretoria.

Learners were asked to indicate which of four possible explanations matched the word being investigated (which in all 16 cases was a very specific Physics term which has a matching lay word which bears little resemblance in terms of meaning). In making the selection, the respondents were also asked to indicate the confidence level with which they were making the selection – in other words, how confident they were that they understood the word. The results were rated both in terms of correctness of understanding and whether the prediction of confidence matched the outcome.

In addition, four lecturers were asked to indicate their prediction of the learners' outcomes – they predicted what percentage of the learners would answer correctly. In this way, the gap between learners' actual knowledge and lecturers' expectations was highlighted.

In an additional exercise, the correlation between the learners' results in terms of correctness and their performance in a standard language proficiency test, Language Proficiency course scores and Physics course scores were investigated. The results showed a very low positive correlation between performance in this study and performance in the Physics and Language Proficiency courses. The results confirmed the existence of a significant gap between learners' perceived knowledge and their actual knowledge. Although the responses of the three participating groups differed from word to word (with some groups scoring higher than others on certain words), overall, the learners' perception of their knowledge differed significantly from their actual knowledge.

Furthermore, a significant difference between lecturers' perceptions and the actual knowledge of learners was shown. On average, lecturers expected their learners to understand the words used 81.02% of the time, while learners only understood the words 48.53% of the time, as shown in the tests.

The study concludes with recommendations (with reference to the literature) for overcoming the gap in vocabulary knowledge between lecturers and learners.

OPSOMMING

Hierdie studie ondersoek en meet die korrelasie (oftewel "gaping") tussen die persepsies wat leerders en lektore het van die leerders se kennis van uitgesoekte Fisikaterme en die akkuraatheid van sulke persepsies.

Verskeie teoretici het die verskille tussen die betekenis(se) wat spesialiste aan sekere woorde heg, en dié wat leke daaraan toeken uitgewys. Een van die primêre bronne van verwarring is die feit dat party items in die wetenskaplike terminologie en woorde in die leketaal identies gespel en uitgespreek word, maar fundamenteel in hulle betekenis verskil. Met verwysing na 'n verskeidenheid sosiale en opvoedkundige navorsers onderskryf hierdie studie die siening dat die lektor en die leerders in 'n Fisika-klaskamer in die hoër opvoedingsmilieu twee verskillende leefwêrelde beklee – elk met unieke (en potensieel eksklusiewe) verwysingsraamwerke. Die sukses van enige Fisika-opleiding in sodanige milieu berus op die leerders en die lektore se vermoë om die begripskloof (of -gaping) tussen hierdie twee wêrelde te oorbrug.

Drie verwante maar onafhanklike sub-dissiplines is gekonsulteer in die navorsing van hierdie verskynsel: opvoedkundige teorie (met besondere verwysing na wetenskaps-opvoeding); semantiek en kommunikasieteorie. Daar is na beginsels vanuit elk van hierdie subdissiplines verwys om aan te toon dat geslaagde wetenskapsopvoeding op die fondasievlak en eerstejaarsvlak van hoër opvoeding tot 'n ewe mate 'n kommunikasie-vraagstuk kan wees as 'n wetenskapsvraagstuk.

Die studie is van mening dat kommunikasie in 'n milieu waar die woordeskat wat noodsaaklik is vir die begrip van die vak nie genoegsaam deur die leerders verstaan word nie, gewoonlik faal. Op grond van 'n oorsig van die relevante literatuur is 'n loodsstudie gedoen wat gebruik gemaak het van 'n aangepaste weergawe van Jacobs se 1989 vraelys. Die vraelys het van respondente vereis om hulle vertroue in hulle woordeskatvermoëns aan te dui en het daarna hulle werklike woordeskatvermoëns getoets. In die hoofstudie is 'n aangepaste formele toets toegepas op beide 216 leerders en vier lektore. Een groep leerders ('n totaal van 100) was geregistreer vir 'n fondasiejaar program, 'n ander groep (59 leerders) was geregistreer vir 'n verlengde program, terwyl die derde groep (57 leerders) geregistreer was vir 'n BSc-kursus in die Fakulteit Landbou en Natuurwetenskappe aan die Universiteit van Pretoria.

Die leerders is gevra om aan te dui watter uit vier moontlike verduidelikings die woord wat ondersoek word (wat in al 16 gevalle 'n baie spesifieke Fisikabegrip was wat 'n ooreenstemmende "lekewoord" het wat min ooreenkoms toon wat die woorde se betekenisse betref). In die uitoefening van hulle keuse is die respondente ook gevra om die vertrouensvlak waarmee hulle die keuse uitoefen, aan te dui – met ander woorde, hoeveel vertroue hulle het dat hulle die woord verstaan het. Die resultate is beoordeel beide op die basis van die korrektheid waarmee die leerders die woord verstaan het en daarop of die vertrouensvoorspelling die uitkoms weerspieël.

Verder is vier lektore gevra om die leerders se uitkomste te voorspel – hulle het voorspel watter persentasie van die leerders korrek sou antwoord. Op hierdie wyse is die gaping tussen die leerders se werklike kennisvlak en die lektore se verwagtinge uitgelig.

In 'n verdere oefening is die korrelasie tussen die leerders se resultate ondersoek in terme van korrektheid en hulle prestasie in 'n standaard taalvaardigheidstoets, hulle Taalvaardigheidskursuspunte en hulle Fisikakursuspunte. Die resultate het 'n baie lae positiewe korrelasie aangetoon tussen die leerders se prestasie in hierdie studie en hulle prestasie in die Fisika en Taalvaardigheidskursus. Die resultate het die bestaan van 'n beduidende gaping tussen die leerders se persepsie van hulle kennis en hulle werklike kennisvlak bevestig. Alhoewel die response van die drie deelnemende groepe van woord tot woord verskil het (party groepe het beter presteer as ander met betrekking tot sekere woorde), het die leerders se persepsies van hulle kennis oor die algemeen beduidend verskil van hulle werklike kennisvlakke.

Verder is 'n beduidende verskil tussen lektore se persepsies en die leerders se werklike kennisvlakke aangetoon. Oor die algemeen het die lektore verwag dat die leerders die woorde 81.02% van die tyd sou verstaan, terwyl die leerders die woorde slegs 48.53% van die tyd verstaan het, soos die toetse aangedui het.

Die studie sluit af met aanbevelings (met verwysing na die literatuur) oor hoe die gaping tussen die woordeskatkennis van lektore en dié van die leerders oorbrug kan word.

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LIST OF ABBREVIATIONS AND ACRONYMS

BICS: Basic Interpersonal Communication Skills

CALP: Cognitive Academic Language Proficiency

ESL: English for Second Language learners

ESS: English and Study Skills

FSK 126: Course code for Physics first-year course at the University of Pretoria presented as part of the Engineering course

L1: First language

LTM: Long term memory

MEDUNSA: The Medical University of Southern Africa

PHY 101: Physics first-year course at the University of Pretoria presented as part of the BSc Extended programme

PHY 181: Physics first-year course at the University of Pretoria presented as part of the BSc Biological Science course

UPFY: University of Pretoria Foundation Year programme in Mathematics and Basic sciences

WITS: The University of the Witwatersrand

ZPD: Zone of proximal development

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CHAPTER 1: ORIENTATION TO THE STUDY

1.1 Background to the problem

Lecturers often assume that learners who enter higher education already have a basic knowledge and understanding of commonly used terms in their chosen field of study. The learners themselves might be working from this same assumption. However, there is generally a high failure rate among first-year learners in Natural Science[1] subjects. Learners' misunderstanding or incomplete understanding of terms on the one hand, or their lack of semantic awareness (the extent to which they are aware of their own understanding of the meanings of terms) on the other, might be contributing factors to the failure rate.

The impetus for this study was given by a paper by Jacobs (1989:395-399) entitled "Word usage misconceptions among first-year university Physics students" which appeared in the *International Journal for Science education.* In the paper Jacobs (1989:395) distinguishes between three kinds of language discourse used in Physics:

standard or "lay" vocabulary;
specialist terminology used only within the discipline; and
standard vocabulary used with a specialist meaning, such as the word "power".

It is the third category that is of concern to this study, because this category is potentially a source of great confusion, and subsequently of poor performance, for learners. Learners think they are familiar with the terms through everyday interaction, but may fail to recognise that these terms are used in a different and very precise context in scientific discourse.

Orr and Schutte (1992:237) also identify this category of seemingly familiar words as problematic. With regard to the language of Physics and Physical Chemistry, they point out that the "chemist also uses words and phrases of 'ordinary' literal and even colloquial English, but it should be realised that new meanings are sometimes attached to familiar words and phrases".

Learners whose "lay" definitions may have been adequate at high school may not realise that a "concept is not an isolated, ossified, changeless formation but an active part of the

[1] When referring to Science as a discipline and Physics, Biology, Chemistry and so on as subjects the words are capitalised.

intellectual process, constantly engaged in serving communication, understanding, and problem-solving" (Vygotsky quoted in Pope & Gilbert 1983:256). A learner's first cognitive definition of a word may therefore never have adapted to include new and more precise scientific meanings and may not have developed to include a range of possible meanings, only one of which is the correct meaning in a particular sentence.

Even experienced scientists do not always concur with each other about the meanings of terms. In *A short history of nearly everything*, Bryson (2003:235) mentions that the term "thermohaline circulation" was used in various leading scientific journals to refer to at least seven different phenomena.

It is not surprising that academics (and therefore learners) have different interpretations of the same words. It is clear when considering the following translations of a Latin text that the translators all had the same general idea, but that their translations in general, and some of the specific terms selected for use in each of these translated versions, differ. In these translations the term of interest is "validis ingentem" (my underlining in each version).

> **Original Latin text**: Quicquid id est, timeo Danaos et dona ferentes. Sic fatus, validis ingentem viribus hastam … contorsit. (Natunewicz 2000)
>
> **Translation by Lind:** Whatever it is, I fear the Greeks even with gifts. So he spoke and with all his strength (he whirled) a great spear…. (Natunewicz 2000)
>
> **Translation by Fitzgerald:** Whatever it is, even when the Greeks bring gifts I fear them, gifts and all. He broke off then and (rifled) his big spear with all his might …. (Natunewicz 2000)
>
> **Translation by Day Lewis:** Whatever it is, I distrust the Greeks, even when they are generous. He spoke: he put forth his strength and (spun) his huge great spear. (Natunewicz 2000)
>
> **Translation by Mandlebaum:** Whatever it may be, I fear the Greeks, even when they bring gifts. And as he spoke he (hurled) his massive shaft with heavy force…. (Natunewicz 2000)

In the above translations, the idea "with all his strength" is also translated as "with all his might", "put forth his strength" and "with heavy force".

The term "force" was investigated extensively by Hart (2002:234-238) in her article entitled: "If the sun burns you is that a force?" After listening to class discussions, she realised that the learners understood the meaning of "force" in both a wider and narrower sense than she expected at the same time. She reports that "on the one hand they did not differentiate between the metaphorical and literal meanings, while on the other hand they did not necessarily regard gentle actions as examples of forces" (Hart 2002:236). Hart (2002:237) mentions that it became clear to her that "semantic shifts" (Arons 1990:50 in Hart 2002) or the development of a meaning for words that was congruent with physicists' meaning(s) was a difficult task for learners.

Hart discusses Klaassen and Lijnse's exploration (1996 in Hart 2002:237) of teacher-learner discourse which shows how "the assumption of identity of meaning may lead to severe communicative failures and misunderstanding". Klaassen and Lijnse (1996 in Hart 2002:237) suggest that what educators label "misconceptions" might actually be failures of communication. Arons (1990 in Hart 2002:234) also concluded that "difficulties with language have the potential to interfere with learners' developing understanding".

Pare (2004) points out that in Hart's (2002) article, "force" is always used as a noun and that in English, "force" is also used as a verb. The meaning changes substantially when the word is used as a verb. Compare "the force" with "forcing something". He refers to two indigenous South African languages where the word "force" is usually used as a verb. Pare (2004) mentions that, in Sotho, the meaning of the word "force" when used as a verb, is similar to the English meaning of the word used as a verb, but that there is no equivalent noun in Sotho which carries the same meaning as the English noun. He adds that in Xhosa the verbal form of "force" is "*ukunyanzela*" and the noun form would be "*inyanzelo*", but that the noun would be a strange construction for a first language Xhosa speaker.

Clearly, given such differences between languages, second language speakers are at a disadvantage when it comes to using English, especially in an academic setting. Cummins (in Shoebottom 2001) refers to two different kinds of language proficiency: Basic Interpersonal Communication Skill (BICS) and the Cognitive Academic Language Proficiency (CALP). BICS refers to the skills of listening and speaking which can be acquired quickly by some people, especially those who have a similar language background to English and who spend a lot of time interacting with English speakers. CALP refers to the ability to cope with academic demands. According to Cummins, many children develop BICS or native speaker fluency, within two years of immersion, but it takes between five and seven years to develop to a native speaker's academic language level.

Cummins (in Shoebottom 2001) warns against assuming that non-native speakers who have attained fluency in everyday spoken English would necessarily have the corresponding academic language proficiency. He warns against labelling learners who have not reached a sufficient CALP level as having "special educational needs", when all they actually need is more time to develop. Lastly, he warns that the non-native speakers in most English for Second Language (ESL) courses are still in the process of catching up with mother tongue peers, even after they have exited from ESL courses.

Cummins (in Shoebottom 2001) believes in the promotion and development of the mother tongue in order to develop to a CALP level in the second language; he states that "[c]onceptual knowledge developed in one language helps to make input in the other language comprehensible". In other words, if a learner already understands the concepts of "force" or "random" in his/her mother-tongue, all the learner needs to acquire the label for the concept in the second language. It makes the task much more difficult if learners have to acquire both the label and the concept in the second language at the same time.

As an example of how obscure meaning can be while using common words, consider Definition 1 of Isaac Newton's (1687) *Philosophiae Naturalis Principia Mathematica* as translated by Andrew Motte in 1729:

> The quantity of matter is the measure of the same, arising from its density and bulk conjunctly. THUS air of double density, in a double space, is quadruple in quantity; in a triple space, sextuple in quantity. The same thing is to be understood of snow, and fine dust or powders, that are condensed by compression or liquefaction; and of all bodies that are by any cause whatever differently condensed. I have no regard in this place to a medium, if any such there is, that freely pervades the interstices between the parts of bodies. It is this quantity that I mean hereafter everywhere under the name of body or mass. And the same is known by the weight of each body; for it is proportional to the weight, as I have found by experiments on pendulums, very accurately made, which shall be shewn hereafter.

It is clear in the above excerpt that most of the words are common English words. Perhaps there are a few which might be relatively unfamiliar (conjunctly, liquefaction and interstices). However, the meaning of the text as a whole is extremely obscure, even to a Physics lecturer to whom the concepts are well-known. Could the definition above be what a Physics lecture sounds like to undergraduate learners? The learners are as unfamiliar with the terminology being used as the lecturers are to the structures being used in the above definition.

1.2 Aims and objectives

1.2.1 Aims

In view of the broad problem area set out above, this study primarily aimed to determine

the semantic awareness of learners regarding their own understanding of commonly used scientific terms;
the extent to which learners actually understand commonly used terms; and
the lecturers' expectations regarding learners' understanding of certain Physics terms.

The secondary aim was to investigate the correlation of actual levels of understanding with the results of Physics and English language courses.

1.2.2 Objectives

In order to achieve the aims mentioned above, the following specific objectives were formulated as research questions:

- What is the learners' perceived level of knowledge of selected scientific words?
- What is the learners' actual level of knowledge of the words?
- What is the learners' actual level of knowledge compared to the level of knowledge expected by the lecturers?
- What meanings do learners associate with certain words?
- What is the learners' level of understanding of the words compared to their final marks in Physics?
- What is the learners' level of understanding of the words compared to their achievement in the vocabulary section of a language proficiency test?
- What is the learners' level of understanding of the words compared to their overall results in the language proficiency test?
- What is the learners' level of understanding of the words compared to their final English course marks?

1.3 Scope of the study

To answer the questions it was necessary to deal with specific sub-sections from three broad fields of study: that of Science education[2], that of communication, and that of language, particularly of semantics.

1.3.1 Science education

From a Science education point of view, the issue revolves around the understanding of terminology as it applies to Physics teaching. By definition, terminology is an agreed-upon set of words with consensual meanings. At the heart of this investigation is the educational problem of determining which of the equally valid meanings of a word is intended by the lecturer and which is understood by the learner.

Few existing studies of this phenomenon have been done so far. There is ample literature about misconceptions regarding Physics concepts, but most refer to the learners' misunderstanding of concepts, and say little about the linguistic and semantic aspects of the teaching interaction.

This study did not deal with misunderstandings *per se*, rather with semantic awareness: where a learner truly believes that he or she understands the usage of a word, and where the lecturer truly believes that the learner clearly understands the terminology. This study tested the accuracy of the learners' belief that they understand the lecturers' intentions, and it showed that, in the majority of cases, the learners did not.

The value of the study does not lie in its showing learners that they are insufficiently semantically aware. Instead, it aimed to illustrate to educators not only the necessity of clarifying the definitions of terminology, but also the need for painstakingly pointing out the differences in meaning between scientific terminology and colloquial usage for the purpose of improving understanding in the science classroom.

1.3.2 Communication theory

At its simplest, communication theory deals with the construction and transmission of messages between a sender and a receiver. More than in almost any other communication

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[2] While informal Science learning is not discussed further, a recommendation with regard to informal language learning is made in Section 5.3.1.

setting, in an educational situation one can easily see that, on the whole, the lecturer is the sender and the learner the receiver. In a lecture (a communication event) there is an entire "cultural" milieu in which the learner finds him/herself. Lecturers and learners find themselves belonging to different "cultures" when it comes to academic matters; the lecturer has been exposed to the academic "culture" for many years and hence takes some of the cultural aspects for granted. In this case, the culture is an academic one, a scientific tradition which alters (by consensus) the meaning of "common" words and re-engineers them to a specialised purpose. The obligation of creating semantic awareness then shifts to the lecturer (sender) who sometimes fails to acknowledge that the way in which the words have been repurposed may not be familiar to learners.

If a lecturer does not acknowledge such differences in meaning and codify the message in an appropriate manner, taking care to become familiar with the levels of understanding of the receiver and gaining some insight into the learners' frames of reference, the message may be largely, or even entirely, lost.

1.3.3 Semantics

In terms of communication theory and language usage, the question at issue is the manner in which language is interpreted by various users and the validity of that usage. The scientific meaning(s) of words can differ from their colloquial or common usage meaning.

From all the available, known words which can be used appropriately, a lecturer selects the one which he/she considers most pertinent. When the lecturer decides to use a word such as "power", it is a loaded word with a very specific meaning, based on the lecturer's years of experience of being immersed in an academic "culture". In other words, the lecturer has achieved a CALP level of language proficiency, while the learner might still be at a BICS level. To the learners, the word "power" seems understandable and clear, the structure of the sentence seems clear and understandable, yet the learner does not realise the word may have been used in a specific context that the learner does not know or understand. A learner might take a very general view of the meaning of the word "power" and might merge elements of all the meanings or associations s/he knows into one generalised meaning, whereas the lecturer has a much deeper knowledge of the various discrete meanings of the word and has probably used the word in a very specific context with a very specific meaning.

The literature review which follows will examine each of these three facets in more detail and show how an understanding of communication theory and semantic awareness in educational situations is essential to educators who wish to teach science successfully.

1.4 Overview of research methodology

In order to complete the study, four different questionnaires were developed on the basis of a literature review. Three questionnaires were administered to Physics first-year and foundation-year learners and one questionnaire was administered to the learners' lecturers. The results of the questionnaires were compared with each other, as well as with the learners' marks in language proficiency courses, Physics courses and a language proficiency test.

This study is deductive, because it attempts to reveal a relationship between semantic awareness, semantic knowledge and grades by investigating empirical evidence in the form of test scores and grades.

1.5 Conclusion

This chapter has outlined the broad problem and has specified the aims and objectives to be pursued in this study. A very brief overview of the research methodology was given.

Chapter 2 discusses literature regarding the communication context and communication theory. It focuses on Berlo's communication model and Mouton's Three Worlds framework.

Chapter 3 discusses the research design and methodology in detail and shows how the questionnaires developed during three different studies: the original questionnaires used by Jacobs (1989), the questionnaires used in the pilot study and the questionnaires used in the main study.

Chapter 4 discusses the results of the questionnaires in detail and shows which of the 16 words included in the main study the learners had most difficulty with. Chapter 4 also reports on the lecturers' assumptions about how well lecturers thought learners understood common words used in the Physics classroom.

Chapter 5, the concluding chapter, briefly answers the research questions asked in Chapter 1 (under "Objectives"), summarises the findings and makes recommendations. Some suggestions for further research are also made.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Many factors which could influence the academic success of learners have been studied. This study examines only one aspect of learner success, namely the understanding of science terminology by learners in higher education. Language is not the only aspect crucial to success at university, but it is a particularly important aspect of academic success, especially for second language learners.

In looking at the matter of Science education, one must acknowledge that learners at a higher education level are engaged in a complex communication event. For second-language learners to follow the argument of a lecturer in class is frequently a challenge, firstly because of the often foreign terminology or the novelty of the subject matter, secondly, because of a less familiar medium of instruction, and, thirdly, for many learners, because of a new environment with new distractions, including their classmates and external noises from beyond the classroom. There may be new technology in the classroom, the accent of the lecturer may be difficult to follow, or the approach to teaching could be different from what these learners are used to.

The performance required of learners may be different too: they may be required to take notes and look at an overhead projection, a hand-out and/or textbook all at the same time. Another hurdle to communication is their own personal concerns: worries about finances, accommodation, upcoming tests and examinations, family issues and so on. As far back as 1973, Seretlo (in Moji 1998:3) commented on the poor performance of particularly African learners in the Sciences, and he identified factors such as domestic background, environment, religious beliefs and an iconoclastic image of science which might influence the success of learners.

The aim of this chapter is to explore relevant literature on problems faced by learners in the science classroom. Literature on this subject can be divided into three fields; research on learner problems in the science classroom could be discussed in terms of communication theory, semantics and Science education. Since most education necessarily occurs in a communication setting[3] and can thus be examined by investigating communication theory, in this study, semantics and Science education have been explored from the perspective of communication theories.

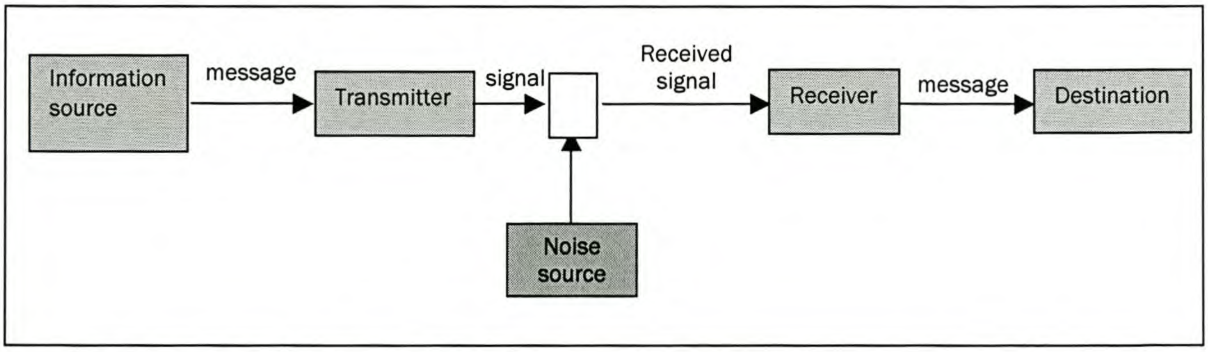
2.2 Communication theory

Several communication models have been developed over the years. This study does not presume to provide a comprehensive overview of the numerous communication models which have been developed. Instead it attempts to discuss a few models briefly to indicate how they contribute to our understanding of communication in the classroom. One model, namely that of David Berlo (1960), is discussed in detail, because it is a simple model, but at the same time addresses several important concepts in communication not discussed by other theorists.

2.2.1 The transmission model and further developments

Many theorists have developed their own theories by drawing on the so-called Shannon-Weaver model which was developed in the 1940's by Warren Weaver and Claude Shannon (see Figure 2.1 below), two employees of the Bell Telephone corporation (Shannon & Weaver 1962).

Figure 2.1: Shannon and Weaver's schematic diagram of a general communication system



Source: Shannon and Weaver (1962:34)

According to Shannon and Weaver (1962:33-35), communication consists of six basic elements:

[3] It is possible, and in fact, probable, that education and even science learning takes place outside the formal class setting, but this type of learning falls beyond the scope of this study.

- a source (person or persons with a purpose);
- a transmitter (in Shannon and Weaver's model, the source is the person doing the communication and the transmitter is the telephone "encoding" the sound message; in person-to-person communication, the transmitter would refer to the speaker's lips, tongue, voice, etc.);
- a message (Shannon and Weaver were not particularly concerned with the meaning of the message, rather the message itself — the words, symbols, and so on);
- a channel (here Shannon and Weaver refer to air waves, paper and ink, cables or whatever medium actually carries the physical message);
- a receiver (this reconstructs the message sent by the transmitter, the ear, for example); and
- a destination (the person for whom the communication is intended).

Shannon and Weaver (1962:65-80) added the concept of "noise", by which they mean any-thing which may cause the received signal to be different from the transmitted signal. They were primarily concerned with physical noise (such as static electricity) which might distort the message so that the message reaches its destination in a changed form.

The Shannon-Weaver model has been criticised for being a "transmission" model, as its view of communication suggests that communication is a simple linear process. (Later, a feedback-loop was added to the model.) It was also criticised for the emphasis Shannon and Weaver place on the technological aspects of communication.

Despite criticism of the Shannon-Weaver model, several communication models have developed from it. One example is Osgood and Shramm's model, developed in 1954, which emphasises the circular nature of communication. Shramm (quoted in Underwood 2003) claims: "In fact it is misleading to think of the communication process as starting somewhere and ending somewhere. It is really endless."

Gerbner's model (cited in Underwood 2003) calls the source an "event", and says that the receiver does not merely see or hear, but interprets the event based on a variety of factors, such as assumptions, attitudes and experiences. Gerbner's model is particularly helpful to this study, because it acknowledges the context in which the communication takes place and attempts to describe the influence of the context on the communication event. (The educational context is discussed in more detail in Section 2.3.3. of this study.)

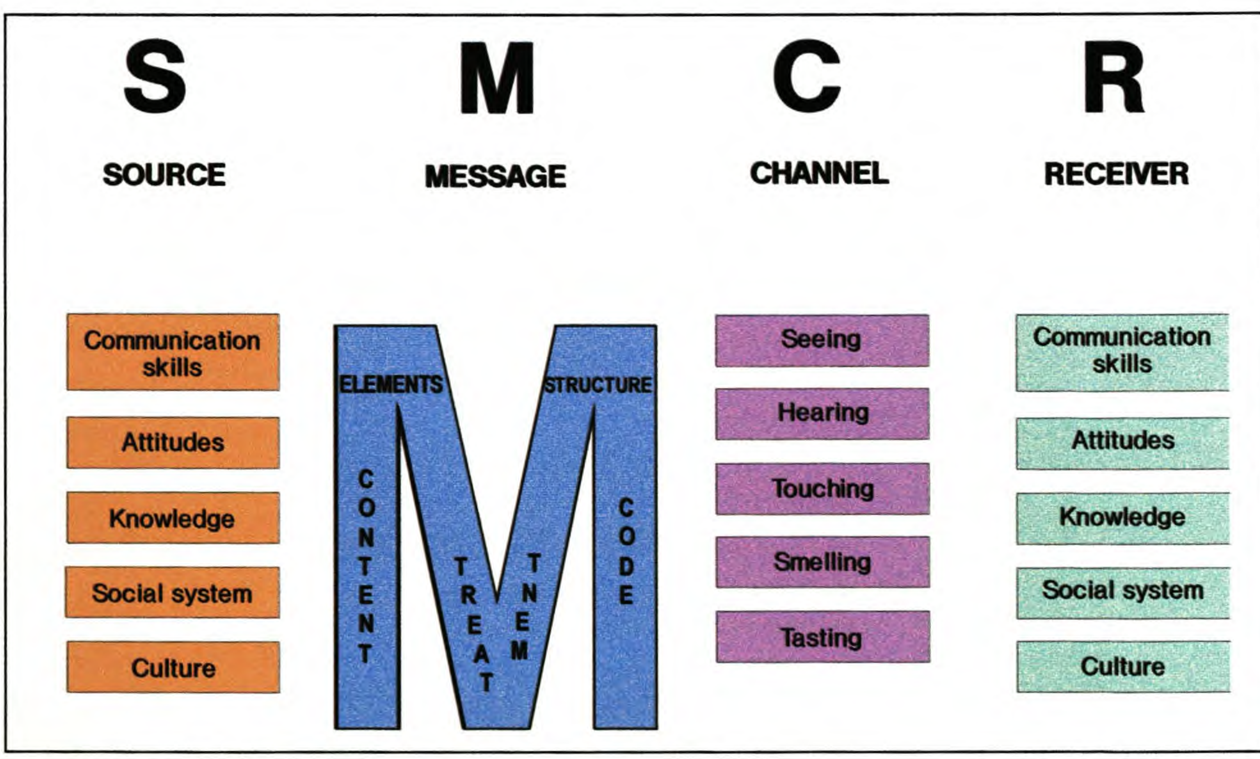
A more recent development in communication theory is Dimbleby and Burton's (1988) model of the self in interpersonal communication (cited in Underwood 2003). The model adds the elements of the intellectual, physical and social, cognitive, emotional and physiological attributes of the self in communication.

It is apparent that there are many different versions of communication models, with slightly different foci. The communication model most suited to this study is the one developed by David Berlo in 1960. The next section discusses Berlo's model in detail.

2.2.2 Berlo's "Source-Message-Channel-Receiver" (S-M-C-R) model

Berlo's (1960) model appears, at first sight, to be simple because it consists of only four main elements: the source, the message, the channel and the receiver. However, Berlo discusses several aspects of each of these elements which makes this apparently simple model comprehensive and allows it to serve as an effective illustration for more complex communication events (see Figure 2.2). Each of these elements is discussed in detail in this section. The various elements form the structure of the literature review below.

Figure 2.2: A model of the elements of communication



Source: Berlo (1960:72)

2.2.2.1 The source and the receiver

Berlo draws on many of the elements used by previous theorists. He acknowledges the aspect of circularity identified by Osgood and Shramm (Berlo 1960:74) and he attributes the same characteristics to both the source of the message and the receiver of the message[4]. Berlo often refers to the person sending the message as the "source-encoder" and to the person receiving the message as the "decoder-receiver". For the purposes of this study, the term "sender" is used to refer to the person sending the message and the term "receiver" is used to refer to the person for whom the message is intended.

Berlo places great emphasis on the role of the relationship between the sender and the receiver. He elaborates on the following elements which are common to the sender and receiver of the message: communication skills, knowledge, a particular socio-cultural milieu and attitudes (Underwood 2003). It follows logically that where the sender and the receiver do not share these elements, communication may be disrupted.

In the case of academic communication between learners and lecturers, the communication events can largely be classified into two situations: the classroom situation and the assessment situation. In the classroom situation, the sender is most often the lecturer, and the learners are the receivers of the message. In an assessment situation, the senders are usually the learners who "send" the message – the test answers or the assignment – to the lecturer, who then acts as the receiver and must decode the message. By its very definition, communication[5] flows in both directions when verbal or non-verbal cues are sent back and forth between learner and lecturer. However, in a higher education setting, the primary sender of verbal messages in the classroom is the lecturer. Lecturers are usually older than the learners, and are seen by both the learners and the lecturers themselves to be the "experts". The success of communication between lecturers and learners, between "experts" and "novices", depends on the four factors discussed in detail below.

(i) Communication skills

According to Berlo (1960:41-45), the successful transmission of the message is influenced by the communication skill levels of the senders and receivers involved in a particular communication event. He argues that a sender may send a message very successfully to

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[4] Whereas Berlo refers to the "receiver" as the person for whom the message is intended, Shannon and Weaver refer to the device used for decoding the message in a physical sense, such as a telephone receiver, as a "receiver" and to the person for whom the message is intended, as the "destination".

[5] Communication, according to the Longman Dictionary of Contemporary English is defined as "the process by which people exchange information or express their thoughts and feelings (Gadsby 1995:266).

one receiver but may fail in a similar attempt with another receiver who has a lower communication skill level.

Von Glasersfeld (1995:141) points out that there is no "direct transmission of the meaning" and that the receiver of a message faces the "task of interpretation". The greater the communication skills of both the learner and the lecturer, the greater the chances of the successful transmission of meaning between the communicating parties.

Since the only "building blocks available to the interpreter" of a message are his/her own subjective conceptualisations, the closer the possible conceptualisation and previous experiences of learner and lecturer, the closer the understood meaning is to the intended meaning (Von Glasersfeld 1995:141).

When considering learners in a communication setting, one should acknowledge that a learner is not "the terminus for communication", and that "his/her active participation in communication must be recognised" (Van Schoor 1986). The learners, then, must become actively involved with the message, must "necessarily be willing and able to receive, decode and interpret the message" (Van Schoor 1986). The communication event does not end with the learner's receiving the message, but also requires the learner to be able and willing to participate in the whole communication event, and to interpret and respond with a new message. The original "receiver" then becomes the "sender".

If communication skills are the basic requirement for successful communication, one could argue that second-language learners (or even lecturers) may be willing to encode the message, but, if English is not their mother tongue, they might lack the skills required to interpret the message or to send back a clear enough message to the lecturer (or learner) for successful interpretation. For communication to be successful, both the sender and the receiver should have at least a certain level of communication skill. The skills used in encoding messages are speaking and writing, while those needed for decoding are listening and reading. In addition to these, reasoning is crucial to both encoding and decoding (Berlo 1960:45).

Underwood (2003) summarises the communication skills needed by both sender and receivers as follows (my bullets):

- knowing and applying the code's grammar;
- knowing and using a broad vocabulary;

- knowing and applying the conventions; and
- adapting the use of the code to the audience.

From this researcher's experience as a language teacher, it seems that many lecturers and learners erroneously assume that they share the same level of communication skill. Von Glasersfeld explains the problem caused by this assumption:

> Given that language users as a rule achieve a great deal of linguistic compatibility with the others of their group, they easily come to believe that the words they use actually refer to objects in a real world, and that, therefore, language does provide a description of things beyond individual experience. The implicit reasoning that leads to this illusion is something like: if so many refer to the same things, the things must be real. But this overlooks the way in which each language user constructs meanings.... (Von Glasersfeld 1995:48)

(ii) Knowledge

It is not only the communication skills but also the knowledge that the sender and receiver share that assist in successful communication. Communication is affected by the source and the receiver's knowledge of attitudes, treatment, channels and subject matter.

If the sender is aware of certain attitudes held by the receiver, for example, towards the subject matter contained in the message, s/he might adapt the presentation of the material to suit the particular audience. The success therefore depends on the sender's level of awareness of his/her own attitude and/or his/her level of awareness of the attitude of the audience the message is aimed at.

Moreover, added to knowledge about the receiver's attitudes, the sender needs to have knowledge about "treatment", because it is the sender who determines how the message is treated. Berlo (1960:60) defines "treatment" as "the decisions which the communication source makes in selecting and arranging both codes and content". The source selects not only the code to use, for example, words or pictures, but also the words to use, for example, "terrorist" versus "freedom fighter", and the style of writing or speaking, for example, academic or informal discourse.

In addition to possessing knowledge of attitudes and the treatment of messages, the lecturer and the learner also need to be familiar with the communication channels available to them. Based on his/her knowledge of communication channels, the lecturer should decide whether the content of the message would be best served by conveying it in the form of a lecture, a practical session, on a tape, in the form of notes, on the board, or even by small group discussion. The learner, when responding (assuming there is the choice of channel available) should also select the most appropriate channel to send a message (a verbal response, written test answer or assignment).

Finally, the lecturer and the learner have to have sufficient subject knowledge in common to make the communication successful. A Physics lecturer might refer to Einstein, Galileo and Newton in passing; if the receiver has no knowledge of these scientists, s/he will completely miss the point the lecturer is making.

(iii) Attitude

The attitudes of the sender and receiver also have an effect on how well the message is communicated. Attitudes towards the subject matter, the receiver and the sender to him/herself can all affect the communication process. Berlo illustrates this by describing a salesperson's (sender's) attitude towards a product. He suggests that it is easier for the salesperson to communicate the attributes of the product successfully if the salesperson has a positive attitude towards the product. Similarly, the salesperson needs to have a positive attitude towards him/herself in order to convince the client of his/her message. The sender also has an attitude (positive or negative) towards the receiver: the receiver's interpretation of the message may be clouded by the way s/he perceives the sender's attitude towards him/her. In his illustration, Berlo suggests that if the receiver perceives that the sender has a negative attitude, even if the persuasive argument is good, the sale is unlikely to be successful because of the negative personal attitudes surrounding it (Berlo 1960:45-48).

(iv) Socio-cultural aspects

In his chapter entitled "Social systems: the matrix of communication", Berlo (1960:133-167) uses the term "role" to include "role-behaviour" (behaviour that is typically associated with people in a certain position in a social system) and "role-position" (the social position given to a person in a certain social system). Communication is important in social systems, because social systems are produced through communication, and once a system is in place, it determines communication within that system – communication and the social system are interdependent.

Knowledge of the social system, or context, plays an important role in the success of any communication event. When people from two different social systems communicate with each other, there is a higher chance of communication failure, even if they are speaking the same language, than when people from the same social system communicate. Berlo (1960:149) attributes this to the absence of predictability. The knowledge of a social system enables the communication participants to predict both others' reactions and their expectations: "Knowledge of a social system can help us make accurate predictions about people, without the necessity of empathising, without the necessity of interaction, without knowing anything about the people other than the roles that they have in the system" (Berlo 1960:149). While acknowledging that being able to predict reactions and exceptions is a valuable tool in communication, it should be pointed out that, especially in the multiracial South African classroom, there is a risk that "prediction" could verge on generalisation or even stereotyping, which could, in itself, lead to communication breakdowns.

The concept of the context of communication is dealt with in more detail in Section 2.3.3.2, when the specific educational context of scientific communication is discussed.

2.2.2.2 The channel

Berlo describes the channel of communication as being the physical means of transportation: the sound waves produced by the sender and carried over to the receiver is one example of a channel. Berlo (1960:66) defines the channel as "the senses through which a decoder-receiver can perceive a message which has been encoded and transmitted by a source-encoder".

The receiver receives information via all five senses, so the receiver not only hears the message, but can also, in a classroom situation, see the lecturer's facial expression and body "language", in addition to which the learner could perhaps even smell or touch part of the "message". Thus, a learner might be able to feel how light aluminium is or smell the effect of mixing together two chemicals. The "touch" or "sight" channel would, for example, not be the most effective way to help learners understand how strong ammonia smells. It is the responsibility of the sender to take into consideration what the best channel for the message is.

2.2.2.3 The message

(i) Content, elements and structure

According to Berlo, the message has three components: the content, its elements and the structure. The content is the actual information contained in the message, while the elements are the words or signs which are used to convey the message. The elements need to be presented in a particular way in order to achieve the source-encoder's goal. This presentation of the elements is what Berlo refers to as the "structure" (Berlo 1960:54-59).

In a science classroom, the message consists of many facets and each is a communicative event in itself, but each also contributes to a larger "message". Some of the types of messages include:

- instructions from the lecturer (such as "... collect a Bunsen burner...");
- questions from the lecturer (for example, "How many moles are there in one gram of carbon?");
- conversations with fellow learners (for example, "What did you do on Saturday night?");
- noises from outside the classroom (for example, an ambulance going by with its siren on); and
- information from the lecturer (such as "The density of oil is less than that of water. The different densities can be observed when we see that oil floats on water").

(ii) Treatment

Treatment has already been mentioned under the sub-heading "knowledge" in Section 2.2.2.1, a section which deals with the kinds of knowledge required by the sender. A message is necessarily treated in some way; the source must decide how to convey the message. So, for example, the source might consider what code to use, how to structure the elements, which elements to select and which channels to use to convey the message most effectively (Berlo 1960:59-63).

(iii) Code

A message must necessarily be embedded in a code, which Berlo (1960:57) defines as "any group of symbols that can be structured in a way that is meaningful to some person". A code may take the form of signs, words or non-verbal communication (such as music and dance). This study restricts itself to examining code in the form of words, and considers particularly those words that can be considered as lay vocabulary used in a scientific or technical manner (Jacobs 1989:395-399). The main task of the sender, according to Berlo (1960:59), is to decide which code to use, which elements of the code to use and how to structure the elements of the code.

2.2.2.4 Noise

Shannon and Weaver define noise as factors which "distort the quality of a signal" (Berlo 1960:40). Berlo (1960:40), however, includes in his definition of noise all factors in any of the "ingredients of communication that can reduce effectiveness" and equates a decrease in "noise" to an increase in "fidelity". By fidelity, Berlo (1960:40) means "complete accuracy".

Physical noise in the channel is one kind of noise which could reduce the fidelity of a message. Van Schoor (1986:47) mentions several possible sources of noise in the classroom ("... physical disturbances such as posters on the walls, other learners, the lecturer's annoying mannerisms, [and] traffic outside the classroom"). Van Schoor (1986:47) adds that learners also have "internal distractions such as the up-coming tests, homework not done, family problems, health issues, social interactions".

The kind of noise discussed in more detail in this study is "semantic noise", or a decrease in the fidelity of the message as a result of a misunderstanding of the meaning of elements of the message. Since the elements of the message in this study refer to words used in the science classroom, in the next section, the term "meaning", in Berlo's sense of the word, is discussed.

2.2.2.5 Meaning

It is in his definition of "meaning" that Berlo has made a highly significant contribution to the literature. There is no element of "meaning" in his communication model, despite the fact that he devotes a whole chapter to "Meaning and Communication" in *The process of communication* (1960). Berlo asserts that "meanings are not in messages", that meaning is not "discoverable", that "words do not really mean anything at all", and that dictionaries cannot provide meaning. He argues instead that "meanings are in people, that meanings are covert responses contained within the human organism. Meanings are learned. They are personal, our own property. We learn meanings, we add to them, we distort them, forget them, change them" (Berlo 1960:175). Fortunately, we usually find other people who share "meanings" with us, which is why we can communicate with each other (Berlo 1960:175).

According to Berlo (1960), communication does not consist of the transmission of meanings, but only of the transmission of messages. Meanings are not transmittable; it is only the messages which are transmittable. Transferring meaning is a much more complex process than speaking a few words or writing a note. He concludes that a "breakdown in communication can be attributed to the false assumption that there is meaning in the message, rather than only in the source and receiver" (Berlo 1960:175). This conclusion lies at the heart of this study because it assesses the meaning which learners construct from the elements in the messages they receive from the lecturer.

It is critical to this study to explore the issue of semantic noise, or, to put it differently, a decrease in the fidelity of the message, or to put it even more plainly, misunderstanding of words used in the science classroom. It has become apparent to the researcher that lecturers and learners often have different conceptions of the meanings of certain words. This premise is now examined with particular reference to Mouton's "Three Worlds" framework (2001:39), which, together with the work of other theorists and researchers, shows that there is indeed a "gap" between learners and lecturers in areas such as knowledge, skills and vocabulary, to mention but a few. In this study, the difference between lecturers and learners in the aforementioned examples are referred to as a "gap". The term "gap" was purposefully chosen because it implies a definite chasm, but also suggests that it is possible to bridge the divide and to arrive at a common point of understanding.

In Section 2.3, "the communication context", the "Three Worlds" framework, the "gap" between learners and lecturers and the language "gap" in the classroom are discussed with particular reference to Science education.

2.3 The communication context

As mentioned previously, all communication events must necessarily occur in a context, which is not only the physical setting, but also the socio-cultural context, or "matrix" as Berlo (1960:133) puts it. Donaldson and Kurtz (1997) comment on the social and the physical setting (such as the classroom) and the fact that the "rules" of communication differ from one setting to another, depending on the reason for the interaction (a meeting or a party, for example) and the role relationship between the communicating parties (friends or boss and employer). Donaldson and Kurtz (1997) mention the physical setting as playing a role in the communication event and discuss issues such as location, time, space, proximity, sound level and air quality.

An educational setting is also a communication setting. The lecturer is generally regarded as the sender, since (on the whole) the lecturer's messages are seen to be "correct" and "important" information which the learners must absorb, understand and remember. The learners then, are generally perceived to be receivers, the classroom or laboratory is (usually) the physical setting, the material the message, while the broader context is the education system.

There are several assumptions which underlie a communication process in an academic context. Firstly, the lecturer usually assumes that s/he speaks the same language as the learners and that the message can be received by the majority of the learners because, as Ayer (1983:174) says in *Language, truth and logic*, "each of us has good reason to suppose that other people understand him, and that he understands them, because he observes that his utterances have the effect on their actions which he regards as appropriate". In addition, the lecturer may also assume that the learners are sufficiently prepared academically and emotionally to be able to cope with the material which is discussed in the class.

Concomitantly, a learner who enters a class has good reason to believe that s/he should be there. If s/he has faith in the educational system, s/he believes that previous teachers and previous exams have adequately qualified him/her to be in that particular grade. S/he can therefore reasonably assume that the content and language used in a particular course is at a level that s/he should be able to understand.

Thirdly, the "message" of an educational setting is the academic material. Both lecturers and learners should, with good reason, believe that the academic content is neither too difficult, nor too easy for learners at that level. They may assume that the material is suitable to learners in terms of the intellectual demands made, that the chosen textbooks are challenging, yet comprehensible.

The academic environment, which includes the classroom, should be conducive to learning and should not confound learning in the learning process. It is assumed that the environment (physical and social) is conducive to learning, and that the environment as a whole facilitates learning.

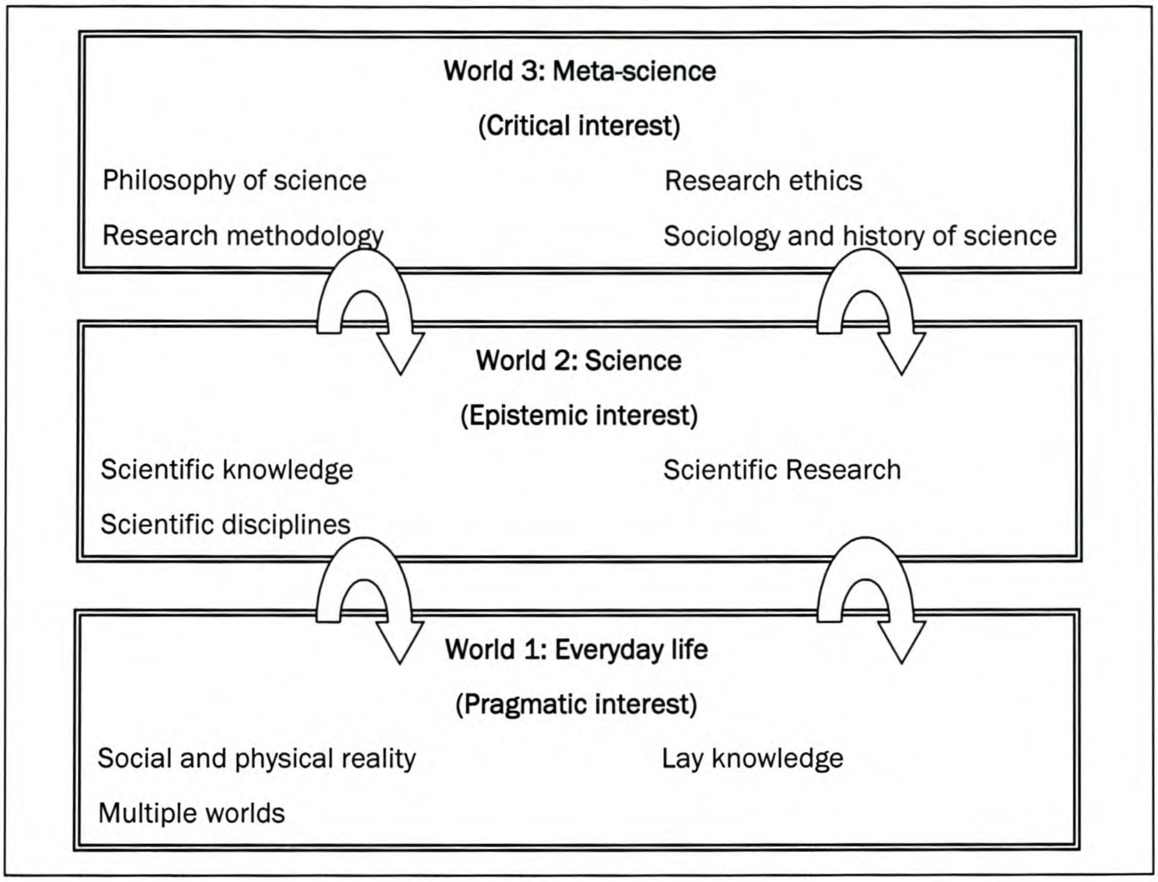
In most education settings, one finds a set of reasonable and strongly held assumptions that everything is, or at least should be, on track for optimal learning. All these assumptions are reasonable. It is assumed by both lecturer and learner that the lecturer can carry over his/her message at the right level. It is assumed that they understand each other – and why not? We are inhabiting the "common world" that Ayer (1983) refers to, and "to assert that two people inhabit a common world is to assert that they are capable, at least in principle, of understanding one another, it follows that each of us, although his sense-experiences are private to himself, has good reason to believe that he and other conscious beings inhabit a common world" (Ayer 1983:175). These assumptions, however, reflect a more uniform world, such as the relatively closed academic environments of the past. They need to be questioned in an increasingly global world, with its demands for uniform communication, clashing with a complex multicultural situation such as that found in most South African universities.

2.3.1 The "Three Worlds" framework

There are several theories of communication, education and philosophy which identify more than one "world", not in contradiction to Ayer (1983), but augmenting his argument of the commonality we share in the physical world and identifying more than one intellectual world. The theories to be examined in this section point towards a factor which complicates the communication events in an academic setting and which question the assumption made by lecturers and learners; that lecturers and learners understand each other.

This study situates the communication event which takes place between lecturer and learner in Mouton's "Three Worlds" framework. Mouton (2001:139) defines "World one" as the realm of lay knowledge, lay words and reality. "World two" is the realm of scientific endeavour, where scientific knowledge is generated and shared, and "World three" is the realm of meta-science where concerns relate to the philosophy of science, the methodology of scientific research and the ethics of Science. Figure 2.3 represents Mouton's basic Three Worlds framework.

Figure 2.3: The "Three Worlds" framework



Source: Mouton (2001:139)

In terms of Mouton's Three Worlds framework, one can clearly see that many, if not most, first-year learners work from a "World one" perspective, using "World one" language and general knowledge such as is available to them, while lecturers and researchers are operating from a "World two" and "World three" perspective, using technical language and advanced concepts. Learners come to class with lay knowledge, lecturers with expert scientific knowledge. Learners come to class with lay vocabulary at their disposal, lecturers use expert and scientific vocabulary. A disruption occurs in the communication because the words sound the same, so that learners and lecturers may not even realise that they are using the vocabulary of different "worlds", from the perspective of different "worlds". For the purposes of this study, the people who are most likely to operate within a certain world view are called, to fit in with Mouton's metaphor of "worlds", the "citizens" of these "worlds".

Figure 2.4: An adaptation of Mouton's "Three Worlds" framework applied to an academic context

Mouton	Language skills	Knowledge	Inhabitants
World three	Meta language skills	Meta knowledge	Researchers
World two	Expert language skills	Expert knowledge	Lecturers
World one	Lay language skills	Lay knowledge	Learners

Mouton implies that learners operate from "World one", but "World two" and "World three" would be the domain of lecturers and researchers respectively. Michelen Chi (in Lipson 1992:92) also makes a distinction between learners and lecturers as being at different levels; he has "demonstrated that 'experts' in a given domain differ from 'novices' not only in terms of greater knowledge but also in terms of how this knowledge is hierarchically and symbolically represented".

Several other researchers also mention this "greater knowledge" and the way that it is structured as a difference between learners and lecturers. Schunk refers (2000:264) to research done by Chiesi, Spilich, Voss and Vesonder in 1979 which shows that a listener's ability to understand depends on what s/he knows about the topic. Comprehension is slower when the long-term memory network ("general" knowledge) is lacking.

Like Chi (in Lipson 1992), Schunk (2000:286) also refers to "experts" and "novices" and says that they differ in terms of the quantity of their knowledge and their organisation of that knowledge. Like Chi, he says that experts possess "more domain-specific knowledge", in addition to which they are "more likely to organise it in hierarchies" than novices in a particular domain, who often "demonstrate little overlap between scientific concepts". He refers to the quantity and organisation of knowledge as the "long-term memory network" (Schunk 2000:286).

Salomon and Perkins (1989 cited in Schunk 2000:209) refer to what they call "high road transfer", which is a function of the long-term memory because of the "expert's" ability to "examine situational cues, define alternative strategies, gather information, and seek new connections between information" (Schunk 2000:211). "Low-road transfer" refers to the transfer of well-established skills in an automatic way, whereas "high-road transfer" is abstract and involves making deliberate connections to other information in the long-term memory (Salomon & Perkins 1989:118 in Schunk 2000:209). Low road transfer would then be the kind of learning that learners usually do at undergraduate level where they might need to memorise and apply a technique, but not evaluate or criticise a theory.

Le Guin (1992) has coined the term "father tongue" to refer to the language used by the "citizens" of Mouton's second and third "worlds", the lecturers and researchers, while learners use the mother tongue or "World one" language. She postulates that the "father tongue" is the language of thought that seeks objectivity (Le Guin 1992:148), and she adds that:

> the dialect of the father tongue that you and I learned best in college is a written one. It doesn't speak itself. It only lectures. It began to develop when printing made written language common rather than rare, five hundred years ago or so, and with electronic processing and copying it continues to develop and proliferate so powerfully, so dominatingly, that many believe this dialect – the expository and particularly the scientific discourse – is the highest form of language, the true language, of which all other uses of words are primitive vestiges. (Le Guin 1992:148)

O'Toole (1996) possibly had a similar idea in mind when he said that there is a characteristically "scientific" style of English. He says that while the users of a scientific language style "consider the style to be a transparent vehicle for the discussion of material phenomena, … research … suggests that it is translucent to those on the edges of the using communities and positively opaque to those outside" (O'Toole, 1996:113). Touger (1991 in Moji 1998:16) has also demonstrated, with his work on words such as "energy" and "force", that concepts and language which may be clear to a physicist or to a teacher are not necessarily so to the learner. McKenna (2004:279) states that "once a discourse is dominant, popular or elevated, it takes on the position of being seemingly 'obvious' and without any ideological or political implications."

It is possible to incorporate the theories of some the researchers mentioned above into a matrix which corresponds to Mouton's "Three Worlds" framework (see Figure 2.5).

Figure 2.5: Matrix of theorists as they relate to Mouton's "Three Worlds" framework

Mouton (2001)	Cummins (Shoebottom 2001, Cummins 2000)	Chi (in Lipson, 1992:92)	Lave (1997)	Schunk (2000)	Salomon and Perkins (1989 in Schunk)	Le Guin (1992:148)	O'Toole (1996:113)
World 3: Meta – language used by researchers to express meta-knowledge		Experts	Master practitioner	Long-term memory network is advanced	High road transfer: deliberate connections to the LTM	Father tongue	Scientific language is translucent for the users
World 2: Expert language, expert knowledge used by lecturers	CALP (Cognitive Academic Language Proficiency)	Experts	Master practitioner	Long-term memory network is advanced	High road transfer: deliberate connections to the LTM	Father tongue	Scientific language is transparent for the users
World 1: Lay language skills and lay knowledge used by learners	BICS (Basic Interpersonal Language Skills)	Novices	Apprentice	Long-term memory network is lacking	Low road transfer: automatic, practise skills in a mindless fashion	Mother tongue	Scientific language is opaque for the user

It would appear then, that the above-mentioned researchers, each in his/her own way, distinguishes between "World one" citizens on the one hand, and "World two" and "World three" citizens on the other. Only Mouton (2001) and O'Toole (1996) distinguish between "World two" and "World three". For the purposes of this study, "World two" and "World three" can be placed in the same category because in a university setting most lecturers are engaged in research and researchers present lectures in addition to conducting research.

It is evident from the work of the researchers summarised above, and the proliferation of bridging and foundation year programmes, that there is indeed a gap between learners and lecturers (the "citizens" of "World one" and "World two" respectively) in several domains; the use and understanding of language and knowledge networks in particular. In the remainder of this study, the "gap" between "World one" on the one hand and "World two" and "World three" on the other is relevant. In discussing the rift between the "Worlds", this study considers the linguistic, semantic and knowledge disparity between lecturers and learners. The "Three Worlds" matrix can be adapted to reflect this gap (see Figure 2.6).

Figure 2.6: Adapted "Three Worlds" framework showing the gap between learners and lecturers

Mouton (2001)	Cummins (Shoebottom 2001, Cummins 2000)	Chi (in Lipson, 1992:92)	Lave (1997)	Schunk (2000)	Salomon and Perkins (1989 in Schunk)	Le Guin (1992:148)	O'Toole (1996:113)
World 3: Meta – language used by researchers to express meta-knowledge		Experts	Master practitioner	Long-term memory network is advanced	High road transfer: deliberate connections to the LTM	Father tongue	Scientific language is translucent for the users
World 2: Expert language and expert knowledge used by lecturers	CALP (Cognitive Academic Language Proficiency)	Experts	Master practitioner	Long-term memory network is advanced	High road transfer: deliberate connections to the LTM	Father tongue	Scientific language is transparent for the users
The "gap" (or Zone of Proximal Development: see Section 2.3.2)							
World 1: Lay language skills, lay knowledge used by llearners	BICS (Basic Interpersonal Language Skills)	Novices	Apprentice	Long-term memory network is lacking	Low road transfer: automatic, practise skills in a mindless fashion	Mother tongue	Scientific language is opaque for the user

2.3.2 The "gap"

Much has been written by a variety of theorists about the causes and implications of this gap between lecturers and learners. The researchers above have identified and described the gap from different points of view, while the following researchers focus on what happens in the gap, rather than merely establishing that a gap exists.

Vygotsky (1978 in Schunk 2000:243) describes a "Zone of Proximal Development" (ZPD) as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers". Slavin (2003:44) suggests that the ZPD "describes tasks that a child has not yet learned but is capable of learning". He goes on to say that some educators refer to "teacher moments" when learners are at a point of readiness to learn a particular concept. Vygotsky's theory suggests that "learning precedes development", and that for development to occur, learning must have occurred first.

Piaget, on the other hand, suggests that development precedes learning. According to Piaget's learning theory, a certain level of development is necessary before learning can take place. Specific "cognitive structures need to develop before certain types of learning" can occur (Slavin 2003:44). Piaget talks about new information or behaviour presented to the learner as being "assimilated" or "grafted" onto "previous schemes" (Piaget 1976 in Von Glasersfeld 1995:62). What is significant about Piaget's theory is the implication that when people learn something new, they can only assimilate "what [they] can fit into the structures [they] already [have]", furthermore, the learner actually "remains unaware of, or disregards, whatever does not fit into the conceptual structures" (Von Glasersfeld 1995:63).

Eggen and Kauchak (1997:31) have adapted Piaget's theory, explaining that as we "acquire experiences, our existing schemes often become inadequate, and we are forced to adapt to function effectively. Adaptation is the process of adjusting our schemes and experiences to each other to maintain a state of equilibrium". They argue that this "drive for equilibrium" is "central to the process of development". The drive for equilibrium is brought about largely by maturation, experiences with the physical world, and social experiences (Piaget 1970 in Eggen & Kauchak 1997:32). Learning, according to Piaget, can be thought of as an active and constructive process in which learners seek organisation and meaning (Eggen & Kauchak 1997: 28-33).

Eggen and Kauchak (1997:27) observe in their chapter on the development of cognition and language that the lecturer "must begin where the learner is". In this statement they concur with Piaget's assertion that teachers must know where the learners "are" so that effective teaching can take place: it is no use trying to teach a three year old calculus, and it would be boring to an 18 year old to have to learn to count to 10! This "readiness" for learning differs from learner to learner. As Eggen and Kauchak (1997:27) indicate, "[t]his nearly self-evident principle has important implications for teachers. If teachers are to be effective, they must have a clear understanding of their learners". The onus rests on the lecturer (the "master practitioner" or "sender") to first assess the stage at which the learner (the "receiver") finds him/herself and provide meaningful activities for the learner to pass through the ZPD from "World one" to mastery at a "World two" or "World three" level.

Lave (1997) uses the term "the apprenticeship approach", which shows that there is "a gap between the actual development and potential development" which the learner can achieve. Sutton (1992:101) concurs with Lave when he says that there is no such thing as a "totally teachable correct method": "...in the context of professional preparation scientists pick up their craft by apprenticeship and not by having it spelled out". Here he implies that there is a stage of apprenticeship before mastery is attained.

Each of these theorists contributes towards an understanding of learning in terms of communication theory. The above literature overview highlights two important aspects: firstly, that there is a gap between learners and lecturers in the aspects of language usage and knowledge networks and, secondly, that learners are capable of narrowing or bridging the gap. The next section of this paper specifically examines the gap in terms of language as it is used in the context of the Science classroom.

2.3.3 The language gap in the Science classroom

2.3.3.1 Language and science

Psychologist David Ausubel (1978 in Wandersee 1988:97), Davidson (in Guttenplan 1975) and Thijs and Van den Berg (in Moji 1998:33-34) all stress the integral relationship between language and thought. In essence, they assert that to express one's concepts and ideas, one needs to do so in language, and in order to use the language skills one has, one has to have thoughts to express. Thought and language cannot be separated from each other.

Block (2002:9) states that "[n]o one can ignore the importance of having a good command of the language in which one is taught". This is even more important when one is attempting to "learn science and all the difficult concepts that involves". Wandersee (1988:346 quoted in Block 2002:9), asserts that "language plays a vital role in helping students acquire new concepts, and concepts are what we think with".

In the summary of the first Science Indaba held at Wits (Pinto 2001), the language session facilitator collated several common language problems in science brought up by participants (see Appendix A). The first two items listed were that a) most concepts are secondary concepts, and they are taught through language, and not through immediate experience, and b) there are new meanings for familiar words, such as table and periodic (Pinto 2001). What is important about these two points is that in the case of a), "World two" concepts are taught, using a mixture of "World one" and "World two" language. In the case of b), "World one" language is sometimes used to refer to "World two" constructs.

Pinto (2001:220) summarises a list of 106 responses (see Appendix B) of perceived barriers to effective communication collected during an informal study at the University of Natal, Pietermaritzburg. It is clear that by far the highest perceived barrier to communication is "vocabulary and terminology".

Block also mentions research conducted by Mogodi and Sanders (1998 in Block 2002) who tested Standard Eight (Grade Ten) pupils' understanding of scientific and everyday English words. They found that only 20% of the pupils understood the terms "coincide", "complex", "excess", "influence" and "sequence", while only 10% of the pupils understood the words "accumulation", "abundance" and "devise". Amosun and Taho (2002 in Block 2002) have also found that learners had difficulties when dealing with words such as "activity", "force", "action", "power" and "strength". Block mentions that Naidoo (2000 in Block 2002) has also questioned the extent to which the understanding of the vocabulary makes the studying of science difficult.

Lipson (1992:95) mentions some of the causes of the "mental chaos" that learners experience in introductory science courses as being due to "common words that have specific scientific meanings, tightly packed symbols, the confusion that attends the early stages of executive knowledge, and the cognitive disarray that results from information overload". Lipson asserts that "[t]hinges all look alike until you are familiar enough with them to tell the differences between them" (Lipson 1992:95).

According to Lipson (1992:93), the word "confusion" is derived from the Latin word "*confundere*", which means "to flow or pour together". He asserts that with the volume of new information that learners must assimilate in introductory courses, it should not be a surprise that "this information gets simply, literally, 'poured together' – concepts that are similar are mistakenly seen as identical; fine distinctions are lost, and discrete bits of information get terribly muddled".

Wandersee (1988:97) points out that even scientists have difficulty in keeping up with new terms. He quotes Tocci (1986), who poses the following question: "[I]s it surprising the public doesn't understand science and the scientist? Sometimes even chemists don't understand the work of other chemists". Wandersee (1988:97) states that communication gaps are even more common between disciplines than within a single discipline. He quotes Sunberg (1986), who observes, "when chemists and life scientists come together and chemists express an effective concentration as 2.3 x 10-4 M, the expression often has little meaning to the life scientists who think in terms of ppm". Sunberg (1986 quoted in Wandersee 1988:97) concludes: "Now if practising scientists encounter such difficulties, imagine what a neophyte biology student must experience!"

Von Glasersfeld (1995:143) explains the ease with which communicators adapt to each other's meanings for words, but points out the difficulties encountered when the concepts are abstract:

> Among proficient speakers of a language, the individual idiosyncrasies of conceptual construction rarely surface as long as the topics of communication are everyday objects and events that have been frequently experienced or talked about by everyone concerned. However, when conversation turns to predominantly abstract matters, it usually does not take long before conceptual discrepancies become noticeable and generate perturbations in the interaction. At that point the difficulties often become insurmountable if the participants believe that their meanings of the words they have used are fixed, independent entities in an objective world that is the same for all speakers. If, however, the participants adopt a constructivist view and begin by assuming that a speaker's meanings cannot be anything but subjective constructs, a productive accommodation and adaptation can mostly be reached.

Block cites research done by Gilbert and Osborne (1980:664), who assert that one of the most difficult and subtle problems in teaching and learning science arise where a learner "believes that understanding of what has been said or read has been achieved, but where this understanding or interpretation is quite different to that which was intended". Ryan (1985 in Block 2002) also says that learners who hear familiar words may assume that they know the meanings and not realise that they are being used in a different context (Block 2002).

It is unfortunate that the very code which has such a need for precision is the one that frequently loses that precision because of its own exacting and non-familiar terminology. Mouton and Marais (1991:14) say that "the requirement that statements must approximate social reality as closely as possible is more highly emphasised in the language game of science than in any other language game" and quotes Lewis (1990 in Mouton & Marais 1991:6) who argue that "the language which can with the greatest ease make the finest and most numerous distinctions of meaning is the best". While English might be able to make "numerous and fine distinctions", it is apparent that when seemingly simple words such as "work" and "force" have respectively 44 and 22 different meanings in a non-technical dictionary (Gadsby 1995:1650-1652 & 550-551), English cannot make these distinctions with "the greatest ease".

2.3.3.2 Second language issues in the science classroom

A further confounding factor for second language learners of science is that the original concept is constructed in another language. This means that not only the vocabulary, but also the whole concept, including what Rutherford (1993 in Moji 1998:32) calls terms with "hidden expectations", "unspoken assumptions" and "underlying beliefs" which exist in the language must be translated.

McKinley *et al.* (1992 in Moji 1998:31) conclude that "since language interacts with thinking, there can be no precise meaningful translation from one language to another since language influences thinking". They conducted a study in 1992 on the effect of language in Science education among the Maori communities in New Zealand. McKinley *et al.* came to the conclusion that "translation can never be just a simple substitution of a term", and that the more the two cultures differ, the more difficult it becomes to translate concepts from one language to another. They found that interdependence of thought and language was very strong in Science education (Moji 1998:31).

It is clear from the extract from Moji (1998) (see Appendix C) that few terms meaning "energy" and "speed" exist in Sesotho. In his interview, Moji points out that there is only one word (*lebelo*) for the concepts "speed", "velocity" and "acceleration" and only one word (*mantla*) for the concepts "energy", "force", "power" and "momentum". Moji's interview was conducted with a teacher who was a subject advisor in the Free State highland region and had been a Physical Science senior primary schoolteacher for sixteen years (Moji 1998:258). In another interview (see Appendix D) with a senior learner whose first language is English, it became apparent that the terms "force", "power" and "energy" are also problematic for first language speakers (Moji 1998:258). For both scientists and language practitioners, it should therefore be no surprise when second language English speakers have language problems in the science classroom.

In research conducted in 1996, Sanders and Sebego (in Moji 1998:35) noted that learners experienced language problems because the Setswana terms which were used in their subjects had a number of English equivalents. In addition, Moji (1998:35) cites research done by Grayson (1996), who warns that since learning Physics is difficult even for mother tongue learners who come from a technologically advanced background, learning about Physics concepts is much more difficult for learners with a limited scientific vocabulary studying in a second language. Howie (2000:29 in Block 2002) has shown that "the majority of pupils tested in South Africa were not fluent in the language of testing ..... and they struggled to communicate". She concludes that language issues "contribute to poor subject knowledge of both teacher and pupil in South Africa".

Cassels (1980 cited in Block 2002) has also shown that second-language learners have a "much poorer understanding of non-technical terms than did their counterparts who were L1 [first language] English speakers". Sithole (in Bird & Welford 1995:389) has reported similar findings among second-language English speakers in Zimbabwe. Specific examples of words that Sithole examined were "omit", "correspond", "standard", "limit" and "factor". He demonstrated that these words caused difficulty in the target learners.

Brock-Utne and Holmarsdottir (1993:78) report that the teachers in their study felt they needed to use isiXhosa even in Grades 5 to 7 because if they were to use only English, "students would look at me like I am crazy". Teachers tend to use the language most likely to help the learners grasp the concept, and that is usually the mother tongue. With regard to the medium of instruction, Moji (1998:5) points out that most African students[6] officially learn science in English, but that the "African science teachers' command of English, especially scientific English, may not be very good". Not only do some teachers lack skills with regard to scientific English, many teachers use the vernacular in the classroom, whether it is against official policy or not. As a result, many learners study the subject in the mother tongue and write the exams in the official language, usually English, or "father tongue", as Le Guin (1992) refers to the official academic language.

Rutherford (1993 in Moji 1998:32) has investigated how language problems were exacerbated by learning in a second language, and she mentions that, although English is used as the medium of instruction for 90% of learners, it is the first language of only about 5% of the whole population. Brock-Utne and Holmarsdottir (1993), on the other hand, claim that learners are very likely to receive instruction in their mother tongue. It seems that currently in South Africa it is not possible to determine how many learners receive mother-tongue tuition at the higher education level; the Department of Education cannot tell how many learners receive tuition in the mother tongue or otherwise (Mbuli, 2004).

From the studies cited above, it is apparent that the language code used in the Science classroom is indeed a problem; that there is what could be called a gap between the language skills and knowledge of lecturers and learners, particularly for second language users.

2.3.3.3 Vocabulary used in the Science classroom

The average first-language adult speaker of English has between 12 000 and 15 000 words at his/her disposal and an educated person has an average vocabulary of about 23 000 words at his/her disposal (Crystal 1988:44). According to Crystal (1988) the 1984 edition of the *McGraw-Hill dictionary of scientific and technical terms* contains about 98 500 terms and more than 20 000 of these terms are considered to be "fundamental" to the understanding of the life sciences alone by the editors of the *McGraw-Hill dictionary of the life sciences*. Considering the vast discrepancy between the vocabulary available to a first-language English speaker and the enormous body of vocabulary which experts regard as "fundamental" when studying a science course, it is not difficult to understand why novice, second-language learners in any scientific field would have trouble in understanding the terminology used in that field (Wandersee 1988:97).

Mayr (1982:45 in Wandersee 1988:99) observes that in Biology in particular, the phrasing of definitions is often problematic and that most definitions need to be modified repeatedly. Mayr (1982:45 in Wandersee 1988:99) points out that it is not surprising that the meanings of words change, "since definitions are temporary verbalisations of concepts, and concepts – particularly difficult concepts – are usually revised repeatedly as our knowledge and understanding grows". Wandersee (1988:99) suggests that learners should be warned that terms evolve and that they should be prepared to encounter different evolutionary versions of terms as they encounter different sources.

Science and Mathematics teaching and learning is not only concerned with the transfer and acquisition of new facts and skills, but also with the development of language. Science students are therefore exposed to large numbers of new terms, "each with their own precise meaning outside familiar context clues, all embedded in an extremely complicated sentence structure" (Bulman 1986:21).

Ryan (1985 in Block 2002) refers to science terms with multiple and conflicting meanings as "multivalent terms". The term "cell", for example, has different meanings in Biology,

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[6] By "African", Moji means "indigenous black people" (Moji 2004).

Meteorology, Chemistry, Mathematics and Nucleonics. She suggests that if we fail to make a conscious effort to point out such conflicting meanings, we should not be surprised if many learners become confused and think science is too difficult for them. Novak (1977 in Wandersee 1988:99) asserts that "[m]any scientific terms are context-dependent, and we must help students notice contextual clues".

Research conducted by Gardner (1971, 1972, 1974, 1980 cited in O'Toole 1996:119) and Cassels and Johnstone (1980 cited in O'Toole 1996:119) in Papua New Guinea, Australia, the Philippines and Britain has indicated that, although many of the scientific and technical words used in the classrooms are explained by teachers, learners also have problems with the meanings of the non-technical terminology which the teachers assumed the learners were familiar with.

David Layzer, a professor at Harvard University, has made much the same observation about Introductory Physics: the problem for the beginning learner is not so much one of learning definitions of new words like "enthalpy" but of learning what scientists mean by apparently familiar words like "particle" and "wave" (Lipson 1992:91-92). Lipson points out that

> … students may initially be confused because they have failed to realise that everyday language and scientific language often use the same words to mean different things. But even if students recognise this – or have it pointed out to them – they may remain puzzled. If they try, as this student does, to draw upon their intuitive understandings of words to make educated guesses about physical events or properties, they quickly find themselves in trouble. If they try, on the other hand, to ignore everyday meanings and knowledge that they bring with them and just accept only the meanings that are given they also find themselves in trouble this time because they have left their smarts at the classroom door. And worse, students who try to make a place for both approaches in their work find themselves uncertain about when to do which – when to rely on their everyday knowledge of words and concepts and when to mistrust it. (Lipson 1992:92)

Several other studies Gardner (1972), Cassels and Johnstone (1983a, 1983b), Donovan (1997:381), Ryan (1985 cited in Wandersee 1988:97) and confirm that learners have problems in understanding "non-technical" or common words which often have more than one highly specific technical meaning. Clark (1997) and Cassels (1978) have shown that it is the non-technical and familiar words used in a science context which prove most problematic to second-language (and often to first language) learners of science. It appears from a study by Cohen *et al.* (cited by Carrell *et al.* 1988:152) that teachers often concentrate on the technical vocabulary when they attempt to facilitate the comprehension of second language speakers, when it was found, in fact, that non-technical terms present more of a problem to learners. Tendencia (1999 in Block 2002) has examined textbook vocabulary in Brunei and has discovered that Grade 4 and 5 children most often mention the words "describe" and "observe" as being difficult for them to understand.

In her thesis, Block (2002) cites Yager (1983:577) who comments that there is "strong evidence that one major fact of the current crisis in Science education is the considerable emphasis upon words/terms/definitions as the primary ingredient of science – at least the science that a typical student encounters and that s/he is expected to master". According to Block (2002), Amosun and Taho (2002:III-9 cited in Block 2002) have shown that Technikon learners understood only 41.46% of the 530 science and technology words on which they were assessed.

Many of the words used in the science classroom are familiar English words. What learners often do not realise is that, although the words sound familiar, they are being used in a new context, and therefore cannot have the same meaning as the words when they are used in a more casual, familiar context. Lipson (1992:91) says it feels to learners as if they have been "thrown into semantic quicksand" when everyday words take on new and different meanings in a scientific context. He quotes a learner, who says:

> I am having trouble with the concept of work. I see it's force times displacement. Why not force times time? The problem is that I expect work to be related to my quotidian understanding of what work is, and how it is measured. It would probably be easier for me if I could ignore the fact that work has an everyday meaning, but I naturally try to understand it, not just accept it, and that can get me into trouble. (Lipson 1992:91)

As is apparent in the learner's quote about "work", it is not the ordinary meaning of the word that is a problem to this learner, but the scientific meaning. The learner recognises the word, but cannot connect the lay meaning to the new scientific meaning of the word. So, language problems crop up in science classes, not only with the specialist terminology, but also with everyday language which is used with specialist meaning.

In conclusion, what is particularly problematic about the use of "ordinary" words in the science classroom is that "everyday familiarity could lead early students of physics to assume accurate understanding in the physics sense, where in fact general lay understanding exists" (Jacobs 1989:395). Lecturers may be using the word with "an intended precision of meaning that does not allow for loose or approximate interpretation" (Jacobs 1989:395), while the learners may not realise that the word is being used in a precise or technical way.

2.3.3.4 Meaning

(i) Introduction

Between 1950 and 1961, Orton and Dieth (Crystal 1988:90-91) conducted a large-scale dialect survey in 313 localities in England. The research subjects were natives of the locality, and were mainly male agricultural workers over the age of sixty. One of the words investigated was "newt". The researchers found that there were 33 different words for and pronunciations of the word meaning "newt". Some of the words given for "newt" were "ask", "eft", "four-legged emmet", "mewt", "mjowt", "padgetty-poll", "swift", "water-swift" and "yolt", amongst other interesting versions. If one simple concept such as "newt" is expressed using 33 different words by a supposedly homogenous population in a country as small as England, is it not possible (in fact, highly probable) that different populations (lecturers, researchers, learners, physicists, chemists, teachers) have different words for scientific concepts or different semantic and conceptual interpretations of words such as "proportional", "density" and "mass"? (During the preparation stages of this research the word "mass" was in fact excluded from the study because the chemists and physicists asked could not agree on the options given in the multiple choice questionnaire.)

If one can see that there is "subjectivity in the construction of linguistic meaning", then, according to Von Glasersfeld (1995:141), "it is no longer possible to maintain the preconceived notion that words convey ideas or knowledge and that the listener who understands what we say must necessarily have conceptual structures that are identical with ours. Instead we come to realise that understanding is always a matter of fit rather than match".

It is therefore not possible to convey meaning. Instead, using only the elements of a message, the decoder-receiver (as Berlo, 1960, refers to the end destination of the message) must construct meaning by using knowledge of various spheres, including his/her knowledge network and knowledge of contextual factors.

Bell and Freyberg (1985 in Moji 1998:15) explain that a message is constructed as follows:

> ... when a teacher teaches, his/her intended message is not automatically transferred to the minds of the pupils. Instead, each pupil constructs his/her own meaning from variety of stimuli including words read or heard. The meanings constructed depend, amongst other things, on how pupils cope with the language the

> teacher uses in instruction. If the language used includes unfamiliar words, unexplained in the pupil's language, comprehension of what is taught will be obstructed.

In other words, because of "semantic noise", the fidelity of the message will be low. While Shannon and Weaver (1962 cited in Underwood 2003) are concerned with physical noise which might distort the message from reaching the receiver, Underwood (2003) states that "it might not be an exaggeration to say that the very essence of the study of human communication is to find ways of avoiding semantic noise".

(ii) Meaning is personal and individual

It is clear from the above example regarding the word "newt" that words and their meanings are problematic. The first point to make about meaning is that the meaning of any word is individualised by the sender and the receiver. No two people have had the same life experiences and it follows that no two people could have exactly the same idea of the meaning of a word. De Saussure asserts that "the meaning of words is to be found in the minds of speakers, rather than in the domain of so-called real objects" (n.d. in Von Glasersfeld 1995:47). So, even though ten people might agree that they understand the word "car" in the sentence "I bought a new car", unless they could actually see the car, they would all have a slightly different idea of what the car might look like, its shape, its size, its engine capacity, its general specifications, and so on.

Von Glasersfeld (1995:48) goes on to say that "learning the language will be seen as a never ending process of adaptation of one's own concepts, governed by the need and the wish to establish mutually compatible associations to the speech sounds one is hearing and producing". Von Glasersfeld could therefore not agree with Vygotsky, who states that a child forms "pseudo-concepts" which are then modified by verbal intercourse with adults until the words the child uses "mean the same to him and to the adult". It is a given that the meanings of words develop as children grow and hear and use a word more and more in different contexts, but no two people have exactly the same idea of the meaning of a word.

Every learner of a language must construct words' meanings from individual experiences and adapt these meanings by trial and error (Von Glasersfeld 1995:137). Von Glasersfeld (1995:137) states that "[t]here is no doubt that these subjective meanings get modified, honed and adapted throughout their use in the course of social interactions. But this adaptation does not and cannot change the fact that the material an individuals' meanings are composed of can be taken only from that individual's own subjective experience". He explains that the notion of "sharing" meaning, in other words, the notion of understanding each other, does not imply sameness but rather a measure of "compatibility in the context of mental constructs" (Von Glasersfeld 1995:137).

Schunk (2000:264) mentions that Just and Carpenter (1992) formulated a "capacity theory of language comprehension" and explain that understanding depends on a "working memory" and that people differ in their "working memory capacity". If knowledge or skill is lacking in one area of language capacity, then, for example, elements understood at the start of a long sentence may be lost by the end (Carpenter *et al.* 1995 cited in Schunk 2000). Those people who have a large "working memory capacity" can maintain the interpretations for a while, while those with smaller capacities maintain only the most likely interpretation of the message (Carpenter *et al.* 1995 in Schunk 2000). With more practice and experience in language situations, people will be able to decide which interpretation is the most likely to be correct (Carpenter *et al.* 1995 in Schunk 2000; King & Just 1991 in Schunk 2000:264). So when learners in a classroom situation are confronted on various sides with "noise" of various kinds, such as the grammar of a second language, a new (scientific) vocabulary and new concepts, their "working memory capacity" fails them.

(iii) Meanings adapt and change over time

In *Studies in words*, CS Lewis (1990:8) uses the analogy of a tree to explain the meanings of words:

> As everyone knows, words constantly take on new meanings. Since these do not necessarily, nor even usually, obliterate the old ones, we should picture this process not on the analogy of an insect undergoing metamorphosis but rather on that of a tree throwing out new branches, which themselves throw out subordinate branches: in fact, as ramification. The new branches sometimes overshadow and kill the old ones but by no means always.

Reiss (1953:4) comments on individual meaning as not being "insulated or self-contained but as extracted, or abstracted, by an active process of differentiation from a background of meaning". If one examines the word "mouse", for example, one can clearly see that the meaning has been adapted considerably in the recent past. Twenty years ago, nobody would walk into a shop and ask for a mouse unless they meant that they wanted a small rodent. In today's technological society, few people would wonder about what you have bought if you say you have bought a new mouse (although, of course, it could be a new pet rodent!). The question is whether learners would necessarily know which meaning is being referred to. In the case of a mouse, the context should alert the receiver to which meaning is intended; the "computer mouse" and the "mouse that ate the cheese" would be used in different contexts. The context of many science words, however, do not seem out of place and therefore do not appear to warrant the learner's considering whether her/his interpretation is the correct one.

(iv) Words have multiple meanings

Not only do words change meaning over time, but words may have multiple meanings at the same time. Jackson and Ze Amvela (2000:53) point out that "the words we use are never completely homogenous in their meaning: all of them have a number of facets or aspects depending on the context and situation in which they are used and also on the personality of the speaker using them".

Lewis (1990:10) warns against taking the language usage of others at face value:

> If we neglect the semantic history of a word we shall be in danger of attributing to ordinary speakers an individual semantic agility which in reality they neither have nor need. It is perfectly true that we hear very simple people daily using several different senses of one word with perfect accuracy – like a dancer in a complicated dance. But this is not because they understand either the relation between them or their history. … Memory and the faculty of imitation, not semantic gymnastics, enable him to speak about sentences in a Latin exercise and sentences of imprisonment, about a cardboard box and a box at the theatre. He does not even ask which are different words and which have merely different senses.

In would seem wise that Science teachers, in particular, take note of this warning and acknowledge that learners do not necessarily realise that there is a difference between "the force of the storm broke the windows" and "the force on the lever caused movement".

Jackson and Ze Amvela (2000:59) point out that "one meaning cannot always be delimited and distinguished from another, it is not easy to say without hesitation whether two meanings are the same or different. Consequently, we cannot determine exactly how many meanings a polysemous word has". They warn that the "lack of boundaries" between meanings is even more problematic for abstract phenomena. According to Jackson and Ze Amvela (2000:53), abstract phenomena "involve distinctions that are largely imposed, because they have no concrete existence without the linguistic form used to refer to them. For example while speakers may point at an object to specify the particular shade of green they have in mind, they would have no such alternative in order to specify the particular aspect of the word equality which they have in mind".

According to Gee (2001 in Block 2002:11), to be part of a semiotic domain, one has to become fluent in that domain. Each domain has its own grammar, and words and symbols have meanings and are combined to take on more complex meanings in the context of a particular domain. It is apparent from the above research that learners and their lecturers are not always part of the same "semiotic domain", or to use Mouton's term, semiotic "world", and that the meaning of every single word in a lecture has different meanings in the minds of every learner and the lecturer.

(v) Context is the key to unlocking meaning

According to Lewis (1990:12), it is the

> ... insulating power of the context which enables old senses to persist, uncontaminated by newer ones. Thus *train* (of a dress) and *train* (on the railway), or *civil* (courteous) and *civil* (not military), or *magazine* (a store) and *magazine* (a periodical), do not interfere with one another because they are unlikely to occur in the same context. They live happily by keeping out of each other's way. (Lewis's italics)

Lewis (1990:11) points out that it is the context that is the "most important principle that enables speakers to give half a dozen different meanings to a single word with very little danger of confusion".

On the issue of context, Von Glasersfeld (1995:142) suggests that the "linguistic items do not supply the conceptual material, but they delimit what is eligible. In English, for instance, almost every word, taken as an isolated item, has more than one meaning. When it is said or written in a sentence, however, the context of communication usually eliminates all but one of the potential meanings. Instances of irresolvable ambiguity are remarkably rare". This is not difficult to accept, particularly when it comes to common nouns such as "I am going to deposit money into the bank" or "I saw them sitting on the bank, catching fish in the river". When considering scientific language, matters become a little more complex; the distinctions are finer and the contexts are similar; in a Science classroom it is quite possible that lecturer might mean the one sense of the word and the learner understands another; while both think the message has been sent and received successfully.

The danger with multiple meanings is, as Lewis (1990:13) points out, that the

> ... dominant sense of any word lies uppermost in our minds. Wherever we meet the word, our natural impulse will be to give it that sense. When this operation results

> in nonsense, of course, we see our mistake and try over again. But if it makes tolerable sense our tendency is to go merrily on.

Learners therefore may interpret the message using the most dominant sense of the word, and not perceive that this has resulted in "nonsense", because there is so much "noise" of various types at the same time in the classroom situation, besides the limited "capacity" of learners in various aspects such as knowledge skills and vocabulary.

Von Glasersfeld (1995:143) says that to "understand what someone has said or written implies no less but also no more than to have built up a conceptual structure from an exchange of language, and, in the given context, this structure is deemed to be compatible with what the speaker appears to have had in mind". The key word is "appears"; the learner grasps what the speaker appears to have had in mind; the learner cannot judge whether that is what the lecturer actually has in mind, so the learner assumes s/he has understood.

That learners erroneously assume they understand is a key concept in this study. Jacobs (1989) also examined word usage misconceptions among first-year university Physics learners. She compared the scores on what learners thought they understood with the scores of their actual understanding on a selection of lay words used in the Science classroom. She found that learners felt they understood many more words than they actually did understand.

2.4 Conclusion

This chapter has reviewed several communication theories, focussing mainly Berlo's (1960) theory to explain how elements of communication affect Science education. Particular attention was given to the context of communication in education in general and Science education in particular, in both the school and higher education context, and to how Mouton's "Three Worlds" framework could be used to understand the gap between the "citizens" of "World one", "World two" and "World three". The language gap between learners and lecturers was explored, particularly with reference to scientific language, the particular problems of second language science learners, vocabulary that is used in the Science classroom and the meaning attached to vocabulary. In the next chapter, the focus shifts to the empirical part of the research.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter discusses the research approach, aims and objectives of this study, as well as the use of a pilot study and the development of the research instruments.

3.1.1 Approach

This research is positivist because it relies heavily on statistics and other factual data. Positivism has been criticised for "[reducing] people to numbers and that its concerns with abstract laws or formulas are not relevant to the actual lives of real people" (Neuman 2003:71). It cannot be denied that the test subjects in this study are reduced to numbers; but for the purposes of this study, the analysis of many subjects' scores is necessary to come to a broad understanding of the relationship, if any, between semantic awareness, semantic understanding and grades. This research is thus undeniably positivist, and attempts to be "scientific" and "objective".

A survey research design was used, because a survey is an appropriate design for collecting large amounts of quantitative data in order to describe an existing situation and to compare sets of data. Morrison (1993:38-40 in Cohen, Manion & Morrison 2002:171) lists, among the advantages of the survey method, that it is economical and efficient and that it makes it easy for a researcher to manipulate key factors and ascertain correlations supported by a large data collection.

3.1.2 Objectives

This research attempts to examine:

- learners' perceived level of knowledge of scientific words as well as their actual knowledge of the words;
- the learners' actual level of knowledge compared to the level of knowledge expected by the lecturers;
- the meaning which learners associate with certain words;
- the learners' level of understanding of the words compared to their final marks in Physics;

- the learners' level of understanding of the words compared to their achievement the vocabulary section of a language proficiency test (in the case of the learners who wrote the language proficiency test);
- the learners' level of understanding of the words compared to their overall results in the language proficiency test (in the case of the learners who wrote the language proficiency test); and
- the learners' level of understanding of the words compared to their final English course marks in the case of learners who completed an English course.

3.1.3 Assumptions

This study assumed that learners would answer the questionnaires truthfully. Another assumption was that, since all the respondents were studying via English as a medium of instruction, they could understand the questionnaires sufficiently well to respond to the instructions as intended.

3.1.4 Conceptualisation

Jacobs (1989:395-399) distinguishes between three kinds of language discourse used in physics:

standard or "lay" vocabulary (words such as "book" or "flame");
specialist terminology used only within the discipline (words such as "velocity"); and
standard vocabulary used with specialist meaning (words such as "function" or "normal").

It is the third category of discourse that is of concern to this study, because this category is potentially a great source of confusion, and subsequently of failure, for learners. Learners think they are familiar with the terms through everyday interaction, but may fail to recognise that these terms are used in a different and very precise context in scientific discourse (as discussed in Chapter Two).

Common English words used in a scientific context were used in a test to determine whether learners clearly understood the meaning of these words in a scientific context. The research undertaken for this study was concerned with discovering more than whether learners understood the words and to what degree; its primary concern was, however, whether the respondents believed that they understood the meaning of the word in the context of a given sentence.

The words and their contexts were selected on the basis of Jacobs's (1989:396) choice of "common" words, as determined by using the following criteria (Jacobs 1989:396): "...words used as basic currency in physics lectures, and for which definition would be assumed unnecessary; and words which in lay context acquire more flexible and approximate meanings." (Table 3.2 lists Jacobs' original sentences, as well as the sentences used in the pilot study and this study as well as a short explanation of how the sentences were changed.)

3.2 Pilot study

The pilot study for this thesis was a research project which was conducted for a short MPhil paper in 1999. The pilot study is briefly reported here because it served as a pilot study for the more extended research set out in this study. The extended study used learners from a different institution, three different learner groups, augmented questionnaires, two additional instruments and additional data in the form of end-of-year marks in two courses to examine the vocabulary aspect of learners' language problems.

The following words were investigated in the pilot study: "phenomenon", "observations", "validity", "precision", "function", "deviation", "normal", "density", "random", "pressure", "distribution", "proportional", "physical", "acceleration", "frequency", "point", "convention", "scientific", "theory" and "error".

3.2.1 Population

The population was all first-year learners taking Physics 1 at universities, technikons and technical colleges in Gauteng in 1999. The unit of analysis was the individual learner.

3.2.2 Sample

The learners used in the pilot sample could be considered representative of a cross-section of South African higher education science learners in the sense that learners from a historically disadvantaged university as well as learners from a historically advantaged technikon and a technical college were included in the sample.

The total sample of 338 respondents in this study consisted of the following:

- 44 Engineering learners from Germiston Technical College;
- 149 Physics learners from Pretoria Technikon;

- 29 BSc Biophysics learners from MEDUNSA; and
- 116 MBChB Biophysics learners from MEDUNSA.

3.2.3 Instrument design

Two questionnaires (Sections A and B) were used in the pilot study. Section A was a questionnaire requiring the respondents to state whether they knew the meaning of a word in a given sentence. Section B was a questionnaire in which the respondents had to indicate whether the word tested in Section A was similar to or different in meaning from four given words.

Jacobs' (1989) original sentences and answers were examined by a language lecturer, four Physics lecturers and a Chemistry lecturer for factual and grammatical accuracy. Some of the items were altered, because they were found to be confusing, either from a Physics point of view or from a language point of view (see Table 3.2).

The revised questionnaires were given to a Chemistry lecturer and two Physics lecturers at MEDUNSA for additional input. Further suggestions were made, and, as a result of intense debate, some items were taken out entirely. So, for example, the sentence containing the word "massive" could not be used, because consensus could not be reached among the group of lecturers regarding the exact meaning of the word or the correct answers. The fact that the lecturers themselves (the subject specialists) could not concur on the meaning of a word such as "massive" points to the problematic nature of scientific vocabulary.

In Section A, the respondents had to assess whether they thought they understood the italicised words in the context of the sentence. The respondents read each sentence and had to respond by marking "1", "2" or "3" on the answer sheet. The responses indicated the following:

1 = Yes (I understand the meaning of this word in this context.)
2 = Some (I have some idea of the meaning of this word in this context.)
3 = No (I do not understand the meaning of this word in this context.)

As was done in Jacobs's 1989 study, the 'No' and 'Some' scores were combined. It was assumed that these learners did not respond positively (did not think they knew exactly what was meant) and that the respondents should be certain about the meanings of scientific words because of the precision of the discipline (Jacobs 1989:396).

In Section B, the respondents' actual understanding of the words used in Section A was tested. In this section, respondents had to react to all four given interpretations of each word by choosing a response. The options were:

1 = Yes, this is the meaning of the word in this context.

2 = No, this is not the meaning of the word in this context.

Each pattern of four responses to a word was marked as a whole. The respondents had to indicate all four interpretations correctly before the pattern was marked 'pass'. If any one (or more than one) response was incorrect, the pattern for that word was marked 'fail'. Learners who were marked 'pass' on a certain word were regarded as having shown a correct and holistic grasp of the meaning of the word within the context of the sentence.

2.3.4 Trial run

A trial run on the questionnaires (Sections A and B) was conducted on 23 learners from MEDUNSA and Technikon Pretoria, at the respective institutions. The answer sheets were assessed and the MEDUNSA respondents were then interviewed.

3.2.5 Reliability and validity

The reliability and validity of the test scores of the pilot test are combined with a discussion of the reliability and validity of the test scores for the research study, and are discussed in Section 3.3.5 and 3.3.6.

3.2.6 Administration of the instruments

Since the instruments were administered by three researchers at different institutions, the researchers set up a test administration protocol to ensure consistent administration of the questionnaires to all four groups. This protocol contained detailed instructions on the procedure to be used in this administration. All three researchers followed this procedure carefully.

The questionnaires were administered at the three selected institutions during a lecture period in June 1999. All the learners who attended the lecture on the day when the test was administered took part in the study. The two questionnaires were administered during the same class period, but they were administered sequentially and separately so that learners could not change answers on Section A based on insights or realisations achieved while completing Section B.

Section A and a computer answer sheet were handed to the learners. The researcher read the rationale of the research to the learners and emphasised that the answers were for research purposes and would have no influence on course marks. The researcher pointed out that no means of identification was required. Learners were given 15 minutes to complete Section A. Section A was then taken in and Section B was handed out. Learners were instructed to keep the answer sheet, as they would also use it when responding to Section B. The researcher read the explanation of how to complete the answer sheet and then allowed the learners 45 minutes to compete Section B. Finally, both Section B and the answer sheets were submitted, and the learners left the venue.

3.2.7 Data analysis

Prof. Schoeman, Head of the Mathematics and Statistics Department at MEDUNSA, assisted in the statistical analysis of the pilot study using the SASS programme. The findings are briefly reported in Chapter 4.

The subjects' responses to the two questionnaires were compared to determine whether the subjects understood the meanings of the terms correctly or did not understand the terms.

Items 1 to 20 (of Section A) were compared to the corresponding answers of Section B which were marked in patterns from 21 to 100 (for example, Items 21 to 24 comprised the pattern for the first word). Whole patterns were marked correct ("pass") or incorrect ("fail").

Score sheets which were incorrectly completed were excluded from the analysis only for those items where there was incorrect or incomplete marking of the score sheet by the respondents. For example, where no choice was made, or where a choice other than the options "1", "2", or "3" had been made for Items 1 to 20 and options other than "1" or "2" for Items 21 to 100, the score for that set of data was excluded.

3.3 Main study

3.3.1 Population

The population for this study was all the first-year Physics learners and Foundation Year Programme (UPFY) learners at the University of Pretoria in 2002. The total number of learners in the population was 648. The unit of analysis was the individual learner.

Physics first-year learners at the University of Pretoria attend one of five different courses, as set out in Table 3.1 below. Medical learners were not included in this population, since they complete only one semester of Physics.

Table 3.1: Physics courses and enrolment at the University of Pretoria in 2002

Course code	Learners taking the course	Number of learners enrolled
UPFY	Foundation Year Programme learners	128
PHY 101	BSc Extended Programme learners	87
PHY 171	BSc learners (general)	69
PHY 181	BSc Biological science learners	111
FSK 126	Engineering learners	564
Total		959

3.3.2 Sample

3.3.2.1 Learners

The UPFY group was selected because the learners in this group are reasonably homogenous in terms of language and academic background; all are in the UPFY programme because they were not considered academically strong enough to enter mainstream studies directly after Grade 12. The PHY 181 learners, on the other hand, are mainstream learners, although some might have entered the mainstream course via UPFY or the Extended Programme (PHY 101), which is a BSc degree course where learners complete Year 1 over two years with additional support.

UPFY learners come from a historically disadvantaged background and use English as a second, third or fourth language, while the learners in the PHY 181 and PHY 101 classes are a mixture of English mother tongue, Afrikaans mother tongue and indigenous language mother tongue speakers. The PHY 181 group was selected because the researcher wanted to compare the UPFY learners with a mainstream group of learners in terms of semantic awareness and semantic knowledge.

Although the PHY 101 learners were at first not available for testing, the lecturer involved in teaching the 101 course requested that they also be tested. Due to time constraints (only one class period was available), the 101 group only completed Sections A and B of the test instrument.

The sample size was 326. This figure includes 128 UPFY learners, 87 Extended Programme learners (PHY 101) and 111 Biological Sciences learners (PHY 181). All the learners who were in class when the questionnaires were administered were included in the study. This strategy could have excluded the weaker learners who had already stopped attending lectures, as well as those learners who felt they did not need to attend lectures (for whatever reason). It is impossible to say how their absence could have affected the research results. One can only speculate that both some weaker and some stronger learners would have been excluded from the study on the grounds mentioned previously and that the research results would have been balanced out by the absence of both very weak and very strong learners.

3.3.2.2 Lecturers

Lecturers were also targeted in this study because it was necessary to establish what lecturers expected the learners to understand. It was felt that the lecturers involved directly in the UPFY programme might have a better understanding of the level of semantic awareness of their learners than lecturers in the mainstream departments would have. The lecturers were therefore asked to complete a questionnaire (Section D, see Appendix H) in which they had to quantify what percentage of learners in the group they taught accurately understood the word in question, in their opinion.

The sample size of the lecturers was 4. There were three lecturers teaching Physics in the UPFY programme and one lecturer teaching the PHY 101 and PHY 181 courses.

3.3.3 Instrument design

In this (main) study, data were collected by means of four questionnaires: Sections A, B, C and D. The design of Sections A and B was largely based on the questionnaires used in the pilot study (discussed above) which used Jacobs's (1989) study as the basis for the items. In addition, the questionnaires were also subjected to peer validation by lecturers in the UPFY Physics department, and, as a result of this peer assessment, several of the items were altered considerably. The table below sets out the sentences used in the Jacobs (1989) study, the pilot study and this study, and gives a brief explanation of how and why sentences were changed.

Table 3.2: Comparison of sentences used in the Jacobs study, the pilot study and in the main study

	Jacobs's sentences	Pilot study sentences	This study's sentences	Comments regarding changes or elimination of the items
1	A mirage is a natural phenomenon.	Light is a natural phenomenon.	Light is a natural phenomenon.	The word "mirage" was changed to "light" to make the sentence simpler. Learners should not have to wonder about vocabulary other than that of the word being tested; many learners might not know what a "mirage" is.
2	Operation of the amplifier was intermittent because of the bad solder joint.			The word "intermittent" was regarded as not being a "lay" word which would be part of the test subjects' general vocabulary. The sentence was eliminated.
3	The observations were made independently.	The observations were made independently.	During the experiment, the observations were made independently.	The sentence was contextualised to make it easier for respondents to understand.
4	The validity of Hooke's Law is questionable.	The validity of the test results were questionable.		"Hooke's Law" was changed to "test results" to make the sentence simpler. The whole item was eventually omitted because the subject specialists felt that the sentence and the possible answers were too technical and would not render useful results.
5	The area of the sphere was measured with poor precision.	The length of the rod was measured with poor precision.		"Sphere" was change to "rod" to make the content of the sentence simpler. The whole item was eventually omitted because the subject specialists felt that the sentence and the possible answers were too technical and would not render useful results.
6	An electron is sometimes described as a massive particle.			This item was omitted because the subject specialists did not agree on the correct answers and meaning of the word within the context of the sentence.
7	The power input to a driver oscillator is a function of the frequency.	The power input to a driver oscillator is a function of the frequency.	The volume of water in a tank is a function of the height of the tank.	The sentence was simplified.
8	The angle of minimum deviation is easily found.	The angle of minimum deviation is easily found.	Close to the North Pole the angle of deviation of a compass needle is large.	The sentence was simplified and contextualised.
9	Surface A is normal to surface B.	Surface A is normal to surface B.	Surface A is normal to surface B.	The sentence was deemed acceptable.
10	The density of material A is greater than that of material B.	The density of material A is greater than that of material B.	The density of material A is greater than that of material B.	The sentence was deemed acceptable.
11	The radioactivity of an atom is a random event.	The radioactivity of atoms are random events.	Collisions between molecules in a gas occur at random.	The context of the word was simplified.

12	A resonance occurs when the frequency of the driving force equals the natural frequency.			The word "resonance" was regarded as not being a "lay" word which would be part of the respondents' general vocabulary.
13	The pressure in the liquid is determined by the depth.	Pressure in a liquid is determined by the depth below the surface of the liquid.	Pressure in a liquid is determined by the depth below the surface of the liquid.	The Physics content in the sentence was corrected.
14	The events showed a Gaussian distribution.	The distribution of the noise was consistent throughout the room.	The distribution of the noise was the same throughout the room.	The sentence was simplified.
15	The area of a triangle is proportional to its height.	The area of a triangle is proportional to its height.	The area of a triangle is proportional to its height and proportional to its base.	The sentence was altered to include the full concept of the proportionality of triangles.
16	The second root of the quadratic equation did not correspond to a physical solution.	A physical change was observed during the experiment.		The whole item was eventually omitted because the subject specialists felt that although the sentence was good, the answer options were too vague and they could not agree on the correct answer(s).
17	An electric charge undergoes acceleration.	The acceleration of a bullet depends on its mass.	The acceleration of a free-falling object is constant.	The sentence was simplified. Physics knowledge about electric charges and mass was excluded from the sentence.
18	The frequency of vibration depends on the stiffness of the spring.	The frequency of vibration depends on the stiffness of the spring.	The frequency of the vibration of a spring depends on the stiffness of the spring.	The sentence was deemed acceptable.
19	The length of the pendulum is a parameter in the equation for the period.			The word "parameter" was regarded as not being a "lay" word which would be part of the test subjects' general vocabulary. The item was eliminated.
20	Newton's laws, strictly speaking, apply only to point particles.	Newton's laws, strictly speaking, apply only to point particles.		Point particles were considered to be too obscure for use in a Physics first-year curriculum. The item was eliminated.
21	By convention the quantity X goes up.	By convention all vectors point in the direction of the force.	By convention we draw vectors so that they point in the direction of the force applied.	The sentence was simplified and contextualised.
22	Drs X and Y conducted a scientific enquiry into the accident.	A scientific inquiry into the accident was conducted.	A scientific inquiry was conducted into the accident.	The sentence was simplified.
23	The researcher has formulated a theory about X.	The researcher has formulated a theory about X.	The researcher has formulated a model about the behaviour of gases.	The word "model" was deemed a better word to use than "theory" since it is more of a lay word than "theory" is. In addition, "X" was replaced with "behaviour of gases" to contextualise the word "model".

24	Many phenomenon in physics can be associated with cycles.			The meaning of the sentence relies too heavily on the understanding of the word "phenomemon" and not on the word in question, and the plural "phenomena" should have been used to make the sentence grammatically correct. The item was eliminated.
25	We are studying error analysis.	We are studying error analysis.	The error in the measurement of the table was large.	"Error analysis" was deemed a difficult concept. The sentence was therefore simplified.

Just as the items in Section A were altered, so the options in Section B were also altered to eliminate the possibility that learners might score a "fail" for a word because of a lack of knowledge about the option, rather than lack of knowledge of the word being tested. Jacobs's (1989) original five options were altered in several cases and reduced to four for the pilot study and further altered and reduced to three for the main study. The reason for this reduction was that some of the options did not make sense, for example, in Item 1, the option "happening or occurrence" was given; there is a difference between a happening and an occurrence, and if respondents wanted to indicate that a "phenomenon" is the same as a "happening", but different from an "occurrence", they could not do so with the option given in the Jacobs (1989) study.

A brief explanation of the format and purpose of the four questionnaires, Sections A to D, is given below.

3.3.3.1 Section A

As in the pilot study, Section A (see Appendix E) determined whether learners thought they understood certain terms commonly used in science classrooms. Section A was designed using a Likert-type three point scale. Respondents needed to choose one of three options:

- I understand the meaning of the word in this context.
- I do not understand the meaning of the word in this context.
- I am not sure that I understand the meaning of the word in this context.

3.3.3.2 Section B

As in the pilot study, Section B (see Appendix F) tested the actual understanding of the terms by the respondents. In Section B, the learners were given three short explanations of each italicised word. The respondents needed to look at each of the three explanations and choose between the options:

- Yes, this is the meaning of the word in this context.
- No, this is not the meaning of the word in this context.

Just as the sentences in Section A were changed, many of the explanations or alternate words in Section B were also changed as a result of discussions with subject and language specialists.

3.3.3.3 Section C

Section C (see Appendix G) was an open-ended questionnaire which required the learners to write down what they thought the words mean in the given sentence. Section C tested how the learners explained the meaning of the italicised words in their own words.

3.3.3.4 Section D

In addition to information collected from the learners, the researcher would argue that because Science teaching and learning is a communication process, and since a communication process necessarily involves at least two parties, information from lecturers is important for this study. Lecturers were therefore asked to complete a questionnaire (Section D, see Appendix H) estimating what percentage of the learners in the target group knew the meaning of each word in the context within which it was used.

3.3.4 Trial run

Thirteen learners from the UPFY group were randomly chosen to complete a trial run of the questionnaire in order to determine whether the sentences and instructions were clear and whether the answer sheet was easy to complete. The trial run was also conducted to determine how much time subjects would need to complete the questionnaires. A group interview session was conducted immediately after the completion of the questionnaires to determine what problems, if any, were encountered with the questionnaires and the answer sheet. No changes were deemed necessary.

3.3.5 Reliability

Struwig and Stead (2001:130) assert that reliability is "the extent to which test scores are accurate, consistent or stable". They also mention the following which could cause error variance:

- The measure's scores vary over time.
- Although test items are intended to be representative of the domain of items for a construct, this is not always the case, thus allowing some people to perform better on the test than others.
- The items reflect different meanings (i.e. the items are ambiguous).
- The test items may be subjectively or inaccurately scored.
- The participants may guess when responding to items.
- The testing environment may distract participants.
- The participants may not be motivated to complete the test. (Struwig & Stead 2001:131).

Not all the above potential problems are relevant to this study, but in order to determine whether the items were clear and unambiguous, a trial run was used to determine the readability and clarity of the instructions in the questionnaires. As a result of the assessment by, and the comments from this trial run, instructions for completing the biographical information were added, some instructions were made clearer and a rationale for the research was included.

Factors increasing the reliability of the test scores for this study were that the answer sheets were scored electronically and the margin of error when scoring by hand was thus eliminated. In addition, the learners answered the questionnaires in their normal lecture halls, so that the testing environment should not have had a negative impact on the learners' performance in this test.

In Section B of the test, some learners may have guessed when they were not sure whether the option given was similar or different in meaning to the word being tested. In 93.75% of the cases where learners answered all four options by guessing, the pattern of answers would be marked "fail", thus showing that the learner did not accurately understand the meaning of the word entirely. There is a chance that a learner might be certain of, say, three of the options, and guess the fourth option. That learner would then have a 50% chance of "passing" that item as a whole. However, in such a case, the learner still had a very good idea of the meaning of a word since s/he was certain of at least three of the options.

The tests for reliability mentioned by Johnson and Christenson (2004:132-139), such as internal consistency, split-half reliability and equivalent forms were not relevant to the questionnaires used in this study, because the meaning of each word was tested in a very specific context.

Neuman (2003:180-181) mentions four ways to increase the reliability of test scores. These are to conceptualise the constructs clearly, to increase the level of measurement, to use multiple indicators of a variable and to use pre-tests, pilot studies and replication. The above-mentioned four ways are examined below with reference to this study.

The sentences within which the constructs were examined were rephrased for the pilot study, and further rephrased for this study, in order to make the items as clear as possible to the respondents completing the questionnaires. Where items seemed to examine two (or more) constructs, the item was simplified. For example, in Item 7, which originally read "[t]he power input to a driver oscillator is a function of the frequency" was changed to "[t]he volume of water in a tank is a function of the height of the tank", in order to test knowledge of the word "function" and not "oscillator" or "frequency".

Neuman (2003:180-181) suggests that an increased level of measurement would increase the reliability. In the case of this study, the learners could have been asked to complete the level of knowledge on a Likert scale of, say, 0% knowledge of the meaning of the word, 10% knowledge of the meaning of the word and so on. In that case there would have been so many categories that it would have made sense to combine the categories into those respondents who said they understood, those who were not sure and those who said they did not understand. Even though there are only three categories which the learners could use to describe themselves in terms of their knowledge of a word, the three categories were the most appropriate and practical for analytical purposes.

A third way to increase reliability, according to Neuman (2003:181), is to use multiple indicators, in other words, to test the same construct in two or more ways. In this study an open-ended questionnaire was given to the learners in addition to the multiple choice questionnaires in order to assess their knowledge of the meaning of the words.

Lastly, Neuman (2003:181-182) suggests replicating past studies, using pre-tests and pilot studies to improve the reliability of test scores. This study used the research methodology and the questionnaires reported by Jacobs (1989), as well as an extensive pilot study.

3.3.6 Validity

Struwig and Stead (2001:18) define validity as the "truth or trustworthiness of the findings". This study attempted to discover the "truth" about learners' perceptions about their level of vocabulary knowledge and actual vocabulary knowledge and the learners were assured that the questionnaires would not contribute to their year marks. In the pilot study, respondents were not required to supply their names on the answer sheet. The researchers hoped that this reassurance would lead to respondents being more honest about their knowledge, that is, that they would not attempt to deceive the researchers. The aim was to get the respondents to answer as truthfully as possible, so that the researchers could assume that the test scores were a reasonably accurate measure of the respondents' self-awareness regarding their semantic perception of certain words, and not of deception by the respondents of the researchers for the sake of gaining marks.

Conversely, because respondents had been assured that the test did not count towards a year mark, some may not have taken Section B seriously and may not have tried to answer the questions accurately. However, this seems unlikely, since, for any one item, at most eight out of 338 respondents marked the answer sheet incorrectly or incompletely. The highest incorrect or incomplete response was for Item 1, the word 'phenomenon', where eight responses were rejected. A possible explanation for this might be that up to that point on the answer sheet, respondents had to mark numbers '1', '2', or '3' as responses. From Item 21 (where the knowledge part of the test begins) onwards the options were '1' or '2'. Respondents may have marked '3' in error, believing they were actually marking the last option, that is '2'.

Neuman (2003:183-194) mentions four types of validity: face validity, content validity, criterion validity and construct validity, two of which will be examined further with regard to this study. In terms of the face validity of the questionnaires, in this study five physicists, two chemists and a language specialist scrutinised and reworked the existing questionnaires. The face validity aspect of the questionnaires was well examined, since academics from four different institutions (MEDUNSA, the University of Pretoria, the Pretoria Technikon (now known as the Tshwane University of Technology) and the Germiston Technical College) and three different subject area specialists (Physics, Chemistry and English) had been involved in assessing and reworking the questionnaires by the time the questionnaires reached the final stage of this study.

Johnson and Christenson (2004:142) suggest answering the following question when examining content-related evidence of validity: "Do the items appear to represent the thing that you are trying to measure?" When examining the above question in the light of the changes made to the questionnaires, it is clear that some of the items were changed because they did not "appear to represent" what was being measured; that is, standard vocabulary used with specialised meaning. Examples of words which were excluded from this study on the basis that they were too specialist to be regarded as "lay" words for a population of first-year Physics learners were "intermittent", "resonance" and "parameter".

In addition to advising researchers to represent the content accurately, Johnson and Christenson (2004:142) also advise researchers to check whether any important content topics have been left out and whether any items are irrelevant or off the point. In the case of this study, academics would be able to argue *ad nauseam* as to a set of words which should be understood in both a lay and specialised context in a first-year Physics classroom. A selection of words was made in order to present a sense of the extent of the problem. This study does not purport to have covered all the words which might fit into the above-mentioned category.

3.3.7 Administration of the instruments

The questionnaires were administered during a class period when all the learners in the course were available at the same time. The researcher administered the questionnaires herself using the administration protocol which had already been worked out for the pilot study and tested on learner groups at MEDUNSA, Technikon Pretoria and Germiston Technical College. Each of the sections was administered separately so that subjects would not be able to change answers in a previous section as a result of information contained in another section of the test instrument.

Four lecturers were given Section D in person and asked to complete it and return it to the researcher. All the questionnaires from lecturers were received back.

3.3.8 Response rate

The response rates of the different groups for different sections of the measuring instrument are summarised in Table 3.3.

Table 3.3: Response rates to Questionnaires A, B, C and D

Sample group	Questionnaires administered	Number in sample	Number of respondents	Response rate
UPFY	Sections A, B and C	128	100	78.12%
PHY 101	Sections A and B	87	59	67.81%
PHY 181	Sections A, B and C	111	57	51.35%
	Total of learners' responses	326	216	66.25%
Lecturers	Section D	4	4	100%

The response rate for the lecturers' group was 100%. The response rate of the UPFY and PHY 101 groups was satisfactory, at 78.12% and 67.81% respectively, while that of the PHY 181 group was disappointing, at 51.35%.

The reason for the high response rate from lecturing staff was that the researcher approached the lecturers and delivered the questionnaires to and collected them from the lecturers in person.

The reason for the high response rate from the UPFY group was that the learners were compelled to attend all activities. Despite this, several (21.88%) learners were not present for the administration of the test, most probably because the test was not administered in an official lecture period and the learners thought that there would be no record of attendance.

Attendance during the administration of the questionnaires to the PHY 101 group was also high, possibly because the learners expected to receive test scripts back in that period.

The attendance of the PHY181 group was low because their class attendance is, according to the lecturer, always low. Learners are not compelled to attend classes, and therefore many do not attend.

3.3.9 Data analysis

The analysis of the data for the main study was done by Mrs Rina Owen of the Statistics Department of the University of Pretoria using the SASS programme. The following aspects were examined statistically:

- learners' perceived level of knowledge of scientific words compared to their actual knowledge of the words;
- the learners' actual level of knowledge compared to the level of knowledge expected by the lecturers;
- the learners' level of understanding of the words compared to their final marks in Physics;
- the learners' level of understanding of the words compared to their achievements in the vocabulary section of a language proficiency test (in the case of the learners who wrote the language proficiency test);
- the learners' level of understanding of the words compared to their overall results in the language proficiency test (in the case of the learners who wrote the language proficiency test); and
- the learners' level of understanding of the words compared to their final English course marks (in the case of learners who completed an English course).

The actual results are reported in Chapter 4.

3.4 Strengths and weaknesses

It was a weakness in the research design that only four lecturers were included in the study. The reason for this small sample was that only four lecturers teach all the target learners. Because the classes' size are large (in the case of PHY 101 and PHY 181), the lecturer to learner ratio is very high. It is therefore unfortunate, but unavoidable, that, although the sample size of learners is large, the sample size of the lecturers is small.

It was a limitation that not all the learners in the sample groups were tested, due to absences from class during the testing session. Another weakness was that, because most of the learners (56 of the 57 learners) in the PHY 181 group had passed a language proficiency test at the beginning of the academic year, there was an English language course mark for only one of the respondents in this group. For the same reason, there were English language marks for only 32.2% of the PHY 101 respondents. As a result of the lack of

English course marks, a comparison between semantic awareness, semantic knowledge, English and Physics marks could not be done for the whole sample group. However, a comparison of the marks achieved on the language proficiency test and the vocabulary section of the language proficiency test with the score on the questionnaire was done for the learners who wrote the language proficiency test (most of the PHY 101 and PHY 181 learners).

A strength of this study is the development of the questionnaires. Several subject and language specialists assisted with the adaptation of the original sentences in Section A and explanations of the italicised words in Section B.

Table 3.4 is a summary of the number of respondents and the percentage responses received from each group of respondents.

Table 3.4: Summary of data available for and response rate of the different groups

Group	Number in sample	Number of respondents for Sections A and B	Response rate for Sections A and B	Response rate for Section C	Percentage of respondents who have Physics marks	Number (and percentage) of respondents who have English course marks
UPFY	128	100	78.12%	78.12%	100%	100 (100%)
PHY101	87	59	67.81%	0%	100%	19 (32.20%)
PHY181	111	57	51.35%	51.35%	100%	1 (1.75%)

3.5 Overview of the research procedure

The research procedure is briefly summarised below.

Step 1 Literature review

Step 2 Choice of Jacobs's (1989) questionnaire as a basis for this study

Step 3 Adaptation of Questionnaires A and B

Step 4 Validation of Questionnaires A and B

Step 5 Piloting of Questionnaires A and B with 23 learners

Step 6 Modification of Questionnaires A and B

Step 7 Design of administration protocol

Step 8 Administration of Questionnaires A and B to learners from MEDUNSA, Technikon Pretoria and the Germiston Technical College

Step 9 Analysis of results

Step 10 Compilation of written report

Step 11 Modification of Questionnaires A and B

Step 12 Design of Questionnaires C and D

Step 13 Piloting Questionnaires A, B and C with 10 UPFY learners

Step 14 Administration of Questionnaires A, B and C to UPFY and PHY181 learners at the University of Pretoria

Step 15 Administration of Questionnaires A and B to PHY101 learners at the University of Pretoria

Step 16 Administration of Questionnaire D to UPFY and Physics lecturers

Step 17 Analysis of results

Step 18 Compilation of written report

As can be seen from the overview above, the research procedures undertaken for this study have been extensive and the research design has developed considerably since the pilot study, as it became apparent to the researcher that lecturing staff also needed to be included in the study. Chapter Four discusses in detail the results for the individual words as well as the relationship between achievement on this study's questionnaires and achievement in Physics and English language courses.

CHAPTER 4: PRESENTATION OF THE DATA

4.1 Introduction

This study focused on two sets of questions. The one set dealt with lecturers' expectations of the learners' semantic knowledge compared to learners' awareness of their own semantic knowledge. The other dealt with the actual semantic knowledge and performance of the learners in the questionnaires. Section 4.2 reports on the findings of the pilot study, while Section 4.3 reports on the findings of the main study. The table below lists the sample groups, the number of respondents in the pilot and main studies and which questionnaires were used in the pilot study and the main studies.

Table 4.1: Sample groups used and questionnaires administered in the pilot and main studies

Study	Sample group	Number of respondents	Questionnaires administered
Pilot study	Germiston Technical College, Pretoria Technikon, MEDUNSA: MBChB, BSc,	338	Sections A and B
Main study	University of Pretoria: UPFY, PHY 101, PHY 181	216	Sections A, B and C (PHY 101 did not complete Section C)
	Lecturers	4	Section D

4.2 Pilot study

The main aim of the pilot study was to determine which words learners thought they understood, but, in fact, did not understand. The learners' responses to Sections A and B were compared to determine whether the learners understood the meanings of the terms or not.

Items 1 to 20 (Section A of the pilot questionnaire, which dealt with words in context) were compared to the corresponding answers given to items in Section B of the pilot questionnaire. Section B's answers were marked in patterns (for example, Items 21 to 24 in Section B comprised the pattern for the first word in Section A). Whole patterns were marked correct ("pass") or incorrect ("fail").

Score sheets which were incorrectly completed were excluded from the analysis only for those items where the respondents marked the score-sheet incorrectly or incompletely, for example, where no choice was made, or where a choice other than the options "1", "2", or

"3" were made for Items 1 to 20, and options other than "1" or "2" for items 21 to 100, the score for that set of data was excluded.

4.2.1 Findings

The table below summarises the data for the pilot study in terms of the total fail and total pass rates and all four categories of respondents, which were:

- the respondents who marked "yes" but who failed,
- those who marked "yes" and who passed,
- those who marked "no" or "some" and who failed, and
- those who marked "no" or "some" but who passed.

Table 4.2: Summary of data for the pilot study

	Word	yes/fail %	yes/pass %	no/fail %	no/pass %	total fail %	total pass %	total yes %	total no %
1	phenomenon	46	9	36	9	82	18	55	45
2	observations	76	8	14	2	90	10	85	15
3	validity	52	7	40	1	92	8	59	41
4	precision	62	6	28	5	90	10	68	32
5	function	49	15	31	6	79	21	63	37
6	deviation	44	5	44	6	89	11	50	50
7	normal	39	22	26	13	65	35	61	39
8	density	50	10	37	3	87	13	60	40
9	random	51	6	41	2	92	8	57	43
10	pressure	52	17	25	6	77	23	69	31
11	distribution	67	6	26	2	92	8	73	27
12	proportional	57	16	22	5	79	21	72	28
13	physical	64	16	19	1	83	17	80	20
14	acceleration	69	17	12	1	81	19	86	14
15	frequency	72	6	19	3	91	9	78	22
16	point	57	1	38	4	95	5	58	42
17	convention	50	7	32	12	81	19	56	44
18	scientific	64	1	34	1	98	2	65	35
19	theory	44	8	43	5	87	13	52	48
20	error	34	10	45	11	79	21	44	56
	Average	**55**	**10**	**30**	**5**	**85**	**15**	**65**	**35**

On average, learners in this study claimed to know the meaning of the twenty words 65% of the time (see Table 4.2, "total yes" column). However, in answering Section B of the pilot questionnaire, the respondents who claimed to know the meanings of words failed to convince the researcher of this understanding 55% of the time (see Table 4.2, "yes/fail" column). Of the total number of respondents, only 10% (see Table 4.2, "yes/pass" column) who claimed to understand the words actually passed Section B, showing that they did, in fact, understand the words.

Conversely, 35% (see Table 4.2, "total no" column) of the respondents claimed not to understand the meanings, or only to understand the words partially in the context within which they were used. Of these respondents, 5% (see Table 4.2, "no/pass" column) actually did understand the words, because they "passed" the test (Section B). Possible explanations for this could be that they were not confident in their own knowledge, that the answer options were too easy or that they were genuinely deluded regarding the extent of their knowledge. There were 35% who claimed not to understand the meaning of the words fully, and 30% "failed" the test, proving that they had a correct perception of their own lack of understanding.

The number of respondents who correctly predicted their outcome (those who marked "yes" and who "passed" and those who marked "no" and who "failed") amounted to 40% (see Table 4.2, "yes/pass" and "no/fail" columns). Those who incorrectly predicted their knowledge (those in the category "yes" but "fail" and those in the category "no" but "pass") amounted to 60% (see Table 4.2, "yes/fail" and "no/pass" columns). While 40% of the respondents seemed to have a correct perception of their own understanding, 60% of the respondents did not.

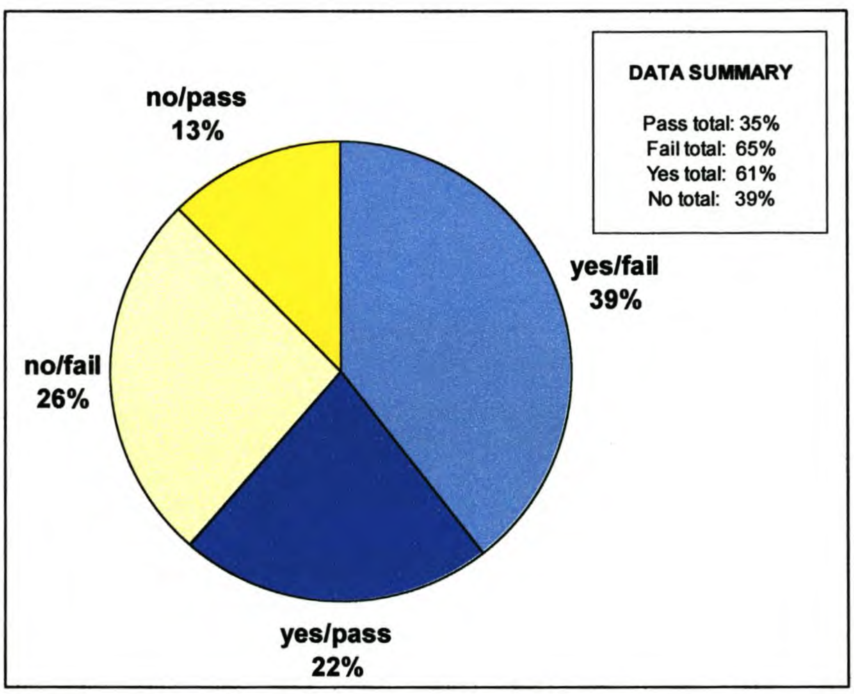
Of the total number of respondents, 85% (see Table 4.2, "total fail" column) "failed" the test. It is a matter of concern that many learners knew that they did not understand basic words such as the ones used in this survey and yet, by June (five months into the academic year when the test was administered), still had not come to understand these words.

The responses to three words deserve special attention. These are "normal", "scientific" and "observations".

4.2.1.1 "Normal"

The responses for the word "normal" (see Figure 4.1) indicate that this was the least problematic word for the respondents in the pilot study. The pass rate for this word was 35%. This was the highest pass rate recorded in the test of 20 words. Even so, 65% of the learners failed to understand this item in its context. Only 22% of the respondents were sure that they understood this word and did indeed understand it (see Figure 4.1, "yes/pass"). This indicates that although this word might have the highest pass rate in this test, it is still a problematic word for learners. They might have understood it in the context of the sentence presented here, but may have difficulty with the word in other contexts.

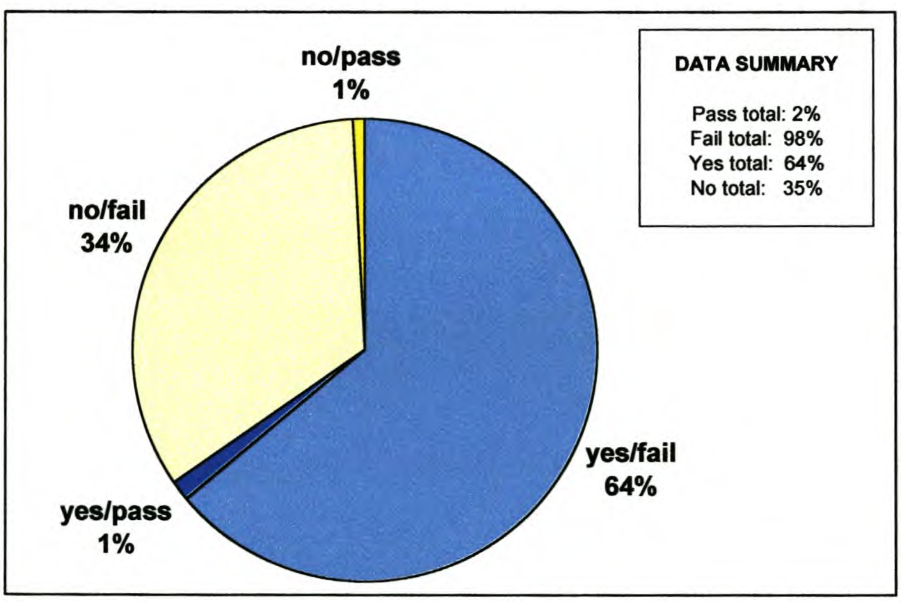
Figure 4.1: Data for "normal"



4.2.1.2 "Scientific"

The word with the highest failure rate in the pilot study was "scientific" (see Figure 4.2). The failure rate was 98%. Only 35% of the respondents felt they did not understand this word. However, a mere 1% of respondents who thought they understood the meaning of the word within the context of the sentence were correct. A possible explanation for this high failure rate was investigated. It was speculated that although the administrator of the tests and the instructions on the questionnaires emphasised that the word should be interpreted within the context of the sentence, the respondents may have read the word in isolation. If this were the case then the option "experimental" should have been the cause of failure, because "experimental" is related to "scientific", but not necessarily in the context of the given sentence. However, an examination of the individual responses to this item showed that the word with the highest incidence of incorrect responses was the option "objective"; 76% of the learners indicated incorrectly that this word did not relate to "scientific" in the given sentence. This seems to indicate that the learners understood the pilot questionnaire correctly and that not only was "scientific" a problematic word, but the four options were also problematic. Regarding the remaining options for this word, the option, "systematic" was indicated incorrectly by 61% of the respondents, "accurate" was indicated incorrectly by 63% and "experimental" was indicated incorrectly by 56% of the respondents.

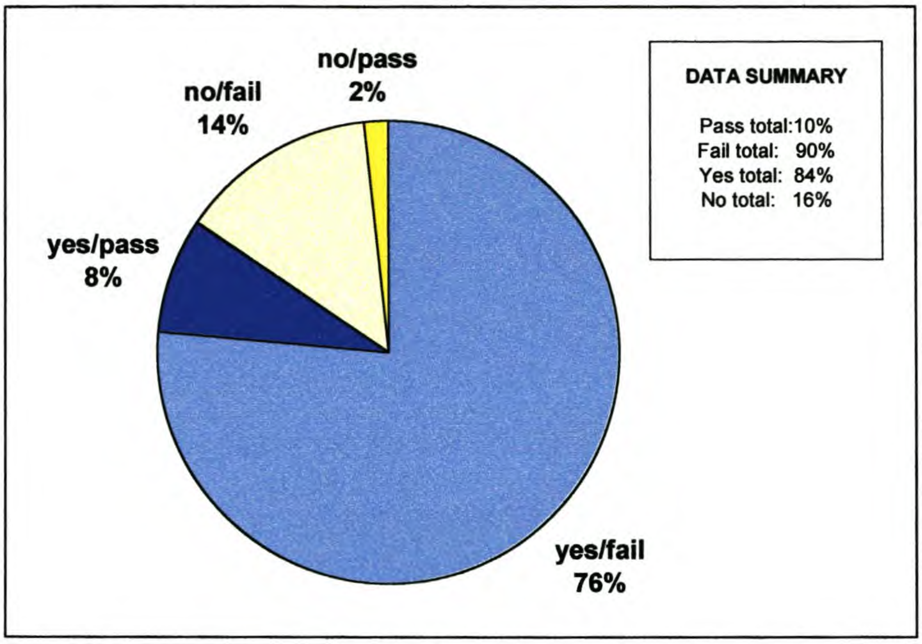
Figure 4.2: Data for "scientific"



4.2.1.3 "Observations"

The third word which seemed problematic to the respondents was "observations" (see Figure 4.3). This word had the highest score in the category "yes/fail" (76%). A total of 84% of the learners felt they understood this word, while only 8% of the learners passed the test. Most of the learners who felt they did not adequately understand the word were correct; 16% of the respondents answered "no" or "some", while 14% failed the test and only 2% passed the test.

Figure 4.3: Data for "observations"



4.2.2 Conclusion of the pilot study

The respondents scored an average of over 20% on only five of the words tested. These were "normal" (35% pass rate), "pressure" (23%), "function" (21%), "proportional" (21%) and "error" (21%). The remainder of the words had a failure rate of 80% and above. In the Jacobs (1989) paper, the words "observation", "precision" and "proportional" had failure rates of 100%, although 80% and more of the learners claimed to understand the words (Jacobs 1989:398). A total of nine words in the Jacobs study had a pass rate of 20% and above. The Jacobs paper reports a 20% pass rate for 36% of the words, while in this study 25% of the words had a pass rate of over 20%.

When Options 21 to 100 were analysed individually, it was apparent that learners not only had problems with so-called scientific words, but also with the range of words supplied as options within the contexts of the given sentences. Some of the words are scientific, while others are common English words which should be understood by learners at the higher education level, for example, "by chance" (failure rate: 77%), "objective" (failure rate: 76%) and "relevant" (failure rate: 74%).

Jacobs (1989:399) asserts that "non-native speakers of English [may be] more alert to their own verbal shortcomings and to the possible ill consequences of vague or approximate interpretations of meaning". In fact, the general scores in the Jacobs study and the pilot study seem to be very similar, despite the fact that the Jacobs study surveyed first-language English speakers and the sample of the pilot study was comprised up to 77% of second language English speakers. The total pass rate for the group of 338 learners who took part in the pilot study was 15% (see Table 4.2), while for the Jacobs study it was 16%. The total number of "correct" patterns in the Jacobs study on Test 2 was 195 out of a total possible correct score of 1250 (Jacobs 1989:398). Inaccurate application of lay vocabulary to scientific contexts thus seems to be a problem for first- as well as second-language speakers of English. The second-language group (as a whole) fared only marginally more poorly than the first-language group.

4.3 Main study

As mentioned previously in Chapter 3, the aims of the main study were to examine

- learners' perceived level of knowledge of scientific words as well as their actual knowledge of the words;
- the learners' actual level of knowledge compared to the level of knowledge expected by the lecturers;
- the meaning which learners associate with certain words;
- the learners' level of understanding of the words compared to their final marks in Physics;
- the learners' level of understanding of the words compared to their achievement in the vocabulary section of a language proficiency test (in the case of the learners who wrote the language proficiency test);
- the learners' level of understanding of the words compared to their overall results in the language proficiency test (in the case of the learners who wrote the language proficiency test); and
- the learners' level of understanding of the words compared to their final English course marks (in the case of learners who completed an English course).

The findings are discussed in five parts: the first part (set out in Section 4.3.1) deals with the general descriptive statistics and examines the results of the three different groups (UPFY, PHY 101 and PHY 181). The second part of the findings (in Section 4.3.2) discusses correlations between the test scores, Physics and English course marks, while the third part (in Section 4.3.3) deals with the learners' actual knowledge of the meaning of the words, as well as the expectations of the lecturers and the semantic awareness of the learners. The fourth part (in Section 4.3.4) discusses the responses received to the open-ended questionnaire. The fifth part (in Section 4.3.5) deals specifically with lecturers' expectations and learners' knowledge.

4.3.1 General overview of the statistics

The one-way analysis of variance (ANOVA) showed that there was a significant difference between the scores of the three different groups (PHY 181, PHY 101 and UPFY). Next, the *post-hoc* Duncan multiple range test (Duncan 1955:1, SASS Institute 1999:1500) was done to determine between which groups there was a significant difference. It was found that the pass marks of the UPFY and the PHY 101 groups were statistically similar. The pass marks of the PHY 101 and the PHY 181 groups were also statistically similar, but the difference between the UPFY group and the PHY 181 group was significant. The mean score out of sixteen for the UPFY group was 7.35, for the PHY 101 group it was 7.59 and for the PHY 181 group it was 8.35. The standard deviation for the UPFY group was 2.18, for the PHY 101 group it was 2.12 and for the PHY 181 group it was 2.51.

There was very little difference between the groups in terms of the scores on the questionnaire determining the actual understanding of the words given in the context of sentences. Of the UPFY and PHY 101 learners, 75% achieved a mark of less than nine out of a possible 16, while 75% of the PHY 181 learners achieved a mark of less than ten out of 16. The highest score out of 16 in the UPFY group was 13, while the highest score in both the PHY 101 and PHY 181 groups was 14.

In general, although the Duncan grouping shows a significant difference between the UPFY and PHY 181 learners, it can be seen that the differences between the three groups in terms of the learners' actual overall understanding of the words is small. Section 4.3.3 discusses differences found between the groups with reference to specific terms.

4.3.2 Correlations

This section discusses the following research aims (mentioned above):

- the learners' level of understanding of the words compared to their final marks in Physics;
- the learners' level of understanding of the words compared to their achievement in the vocabulary section of a language proficiency test (in the case of the learners who wrote the language proficiency test);

- the learners' level of understanding of the words compared to their overall results in the language proficiency test (in the case of the learners who wrote the language proficiency test); and
- the learners' level of understanding of the words compared to their final English course marks (in the case of learners who completed an English course).

4.3.2.1 Physics marks

The correlation co-efficient of the survey scores on Section B with the final Physics marks was 0.31488 for the UPFY group, and 0.02201 and 0.44686 for the PHY 101 and PHY 181 groups respectively. Although these correlations are positive, they are low, particularly that of the PHY 101 group. There is thus not a significant correlation between scores on this test and the scores achieved in Physics courses. This is surprising, because it implies that the anticipated strong correlation between language and academic achievement in Physics does not apply. However, this test only investigates 16 words out of thousands of words used in the Physics classroom, so that a lack of correlation between these test scores and Physics marks does not necessarily mean a lack of correlation between language skills and academic competence on the whole.

4.3.2.2 Language proficiency test scores

The test scores also had a low positive correlation with both the vocabulary section of the language proficiency test and the language proficiency test as a whole. No learners in the UPFY group wrote the language proficiency test, so there were only scores for the PHY 101 and PHY 181 groups. The correlation between the vocabulary section and the PHY 101 questionnaire score was 0.19205 and 0.29396 for the PHY 181 group. The correlation coefficients for the language proficiency test as a whole were 0.27501 and 0.12438 for the PHY 101 and the PHY 181 groups respectively. These are low correlations and would lend some support to the view held by some at the University of Pretoria that the language proficiency test that was used on these groups of learners was not fully suited to these learners' needs. The proficiency test has, in fact, been redesigned since this research study was undertaken. Once again, it needs to be stressed that, since only 16 words were investigated, the test scores do not necessarily imply a low correlation with other words and/or the redesigned proficiency test.

4.3.2.3 Language course marks

UPFY learners attended the English and Study Skills course (ESS), while the PHY 101 learners attended a course in academic language literacy. The PHY 181 learners had to have passed the language proficiency test at the beginning of the year and as a result did not attend any language courses. Once again there was a low positive correlation between the language courses and the scores on the questionnaire for the 16 words investigated. The UPFY group's correlation coefficient was 0.18983. That of the PHY 101 group was higher, at 0.30278. Although positive, neither of these showed a strong correlation with the test scores.

4.3.2.4 Correlation conclusion

In all cases there was a low positive correlation between the test scores and the Physics, Proficiency Test and English course marks. This low correlation might be due to the small number of words selected for the study (only 16) or due to a design fault in the questionnaires or proficiency tests, or it could even indicate that understanding terminology is not an important requirement for academic performance.

4.3.3 Discussion of semantic knowledge and expectations

This section discusses the learners' perceived level of knowledge of scientific words in addition to their actual knowledge of the words, as well as the learners' actual level of knowledge compared to the level of knowledge expected by the lecturers. The discussion here is therefore similar to the discussion of the pilot study.

- The results show four distinct groups in terms of the learners' responses:
- learners who thought they knew the meaning of the words, but in fact did not (shown as "yes/fail" in the graphs below);
- learners who thought they knew the meaning of the words, and who, in fact, did (shown as "yes/pass");
- learners who thought they did not know the complete meaning of the words (the learners who chose "no" or "some"), and, in fact, did not (shown as "no/fail"); and
- learners who thought they did not know the complete meaning of the words (the learners who chose "no" or "some"), while, in fact, they did understand the meaning of the words (shown as "no/pass").

It is important to note that of the four possible results shown, there are actually just two statistical values – the results are binary in that there is either a perfect correlation between individual learners' perceptions and the reality (whether the answer is right or wrong) or a zero correlation between what they think they know and what they in fact know (irrespective of whether the answer is right or wrong).

Another dimension is how closely the expectation of the lecturer matched the actual knowledge of the learners. There is also an issue of perception and reality. The lecturers' personal knowledge of the words is not examined, but rather the lecturers' perception of the learners' knowledge. This is possibly more important because it is an indicator of a possible area of breakdown in the communicative interaction between lecturer and learner.

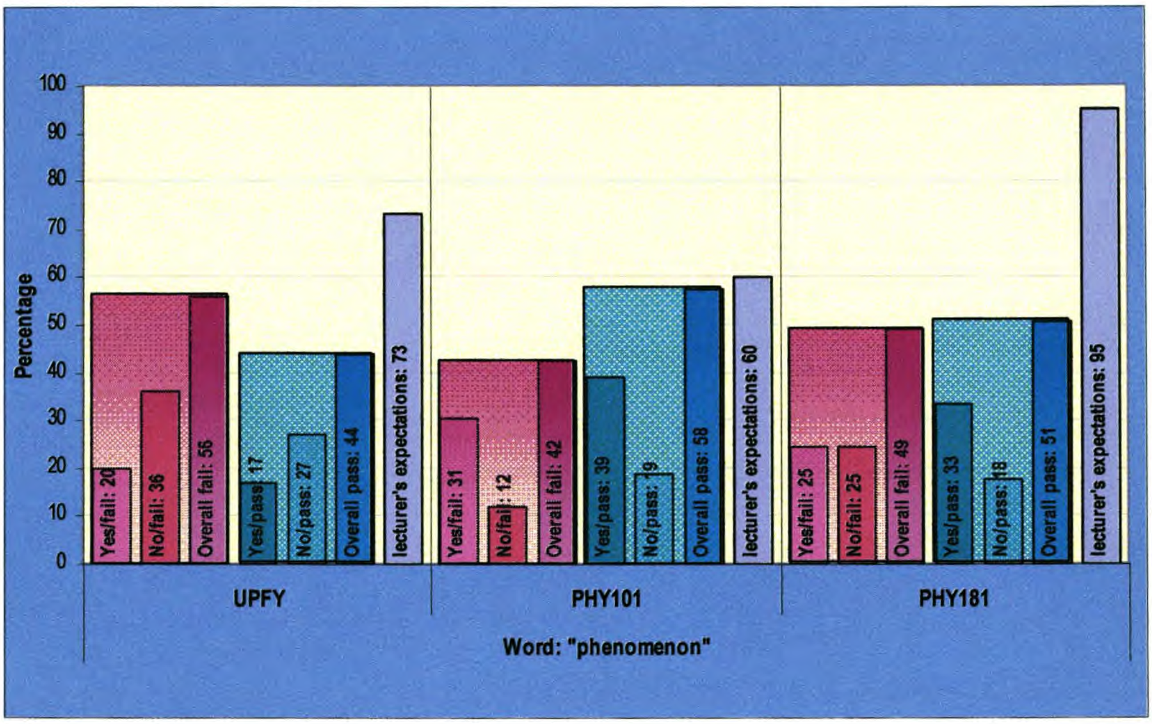
The results for the 16 different words tested in the main study are discussed below in terms of learner and lecturer expectations, and fail and pass rates for the three groups (UPFY, PHY 101 and PHY 181). Because the graphs are self-explanatory and in order to prevent needless repetition, only remarkable results are highlighted.

4.3.3.1 "Phenomenon"

In Figure 4.4, the three sets of results from the three different classes are illustrated. Of the UPFY group, 20% of the respondents believed that they knew what the word "phenomenon" meant in context, but, in fact, they did not (labelled "yes/fail" in the figure). Of the respondents, 17% thought they knew the meaning of the word, and, in fact, did (labelled "yes/pass"). An additional 27% thought they did not know what the word meant, but, in fact, they did know. In all, 44% knew the meaning of the word ("overall pass"), although only 17% thought they did. Of the respondents, 56% did not have the right answer, although only 36% thought that they would get it wrong.

The patterns for the other two classes (PHY 101 and PHY 181) were broadly similar, but not identical. Noteworthy is the lowered expectation with regard to the PHY 101 class. In Figure 4.4 one can discern that the greatest discrepancy between class and lecturer lies in the PHY 181 class. The lecturer expected that 95% of the class would understand the meaning of the word, whereas only 51% actually did. One could argue that there is a gap in understanding of 45% in the PHY 181 class with regard to the understanding of the word "phenomenon". In the PHY 101 class there was a close correspondence between the lecturer's[7] expectation (60%) and the reality in the class (58%).

Figure 4.4: Responses and expectations for the word "phenomenon"



4.3.3.2"Observations"

"Observations" had the highest score in the category "yes/fail" (76%) in the pilot study. In the main study there were not as many "yes/fail" respondents on this item as in the pilot study. The "yes/fail" score ranged from 37% to 54% (see Figure 4.5).

The pass rate on the item was 44% for UPFY respondents, 58% for PHY 101 respondents and 54% for PHY 181 respondents, while in the pilot study only 8% of the respondents passed the test. Although the pass rate on this item was much higher than that in the pilot study, it is of concern that the lecturers expected the learners to know the meaning of the word 95% of the time for UPFY learners and 100% of the time in the case of the two PHY groups, while in fact, the learners' level of knowledge was only slightly more than half of what the lecturers expected.

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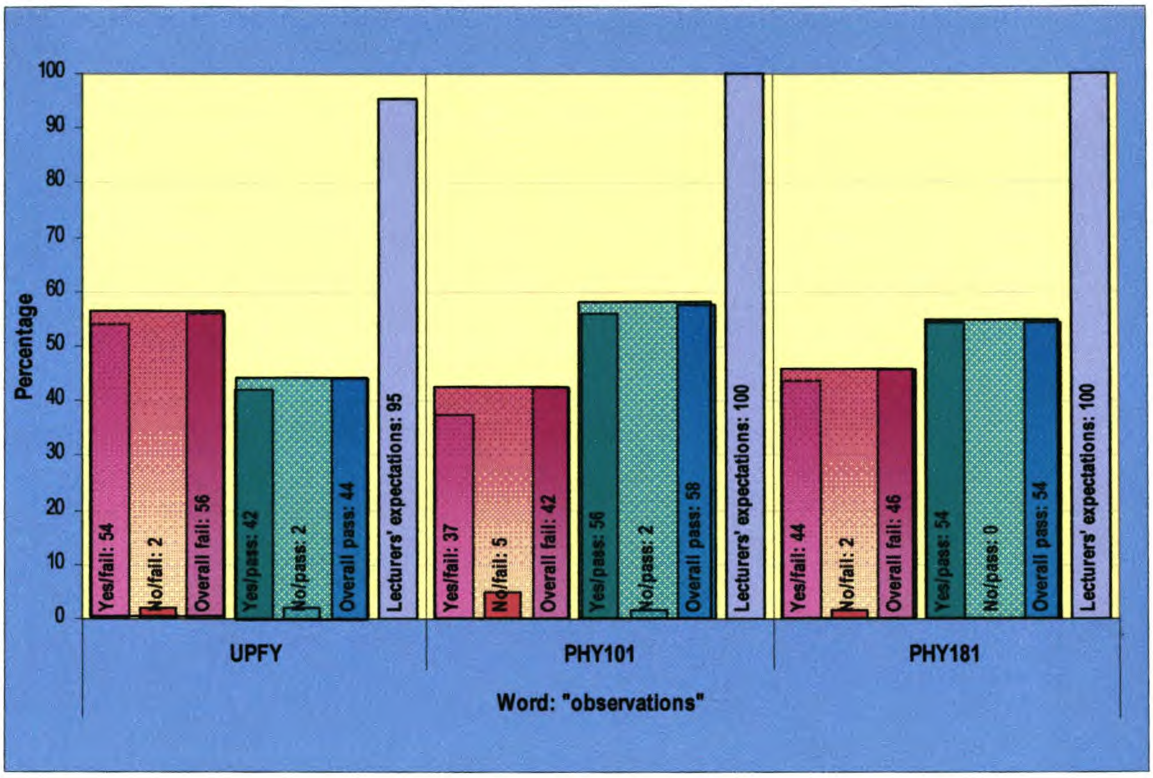
[7] In this study "lecturer" (and "lecturer's") is used when referring to the only lecturer of the PHY 101 and PHY 181 groups, while "lecturers" (and "lecturers'") is used when referring to the four UPFY Physics lecturers.

Figure 4.5: Responses and expectations for the word "observations"

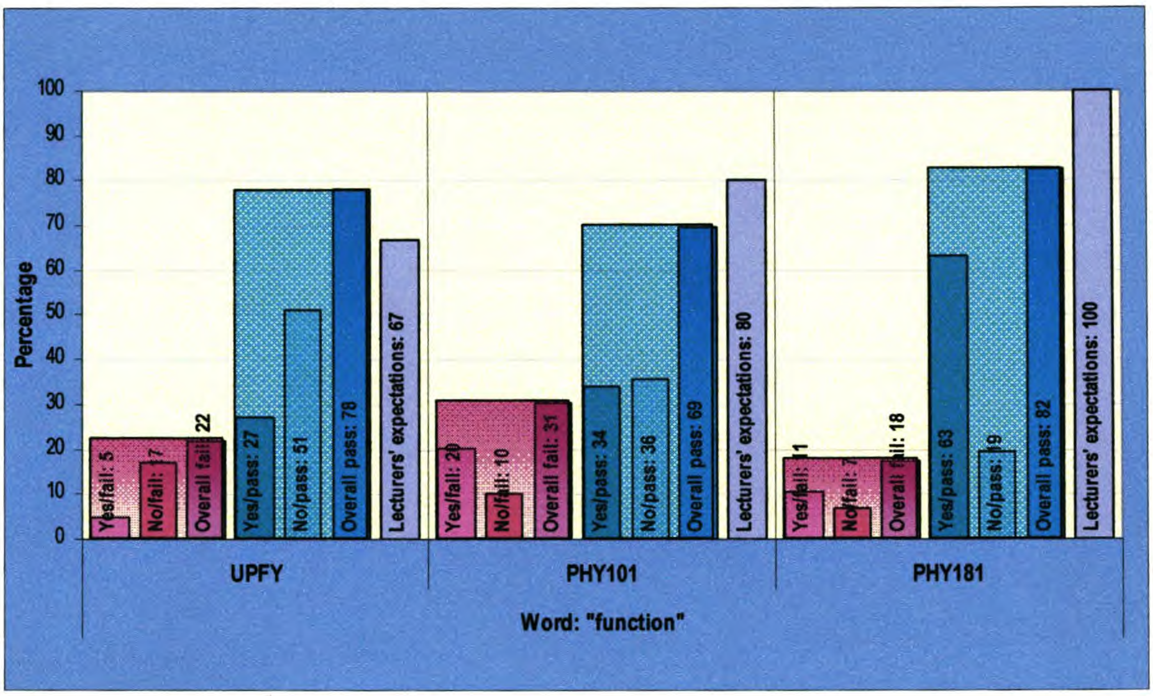


4.3.3.3 "Function"

The overall pass for the word "function" was reasonably high. Of the UPFY respondents, 78% passed, as did 69% of the PHY 101 respondents and 82% of the PHY 181 respondents (see Figure 4.6).

Despite the fact that so many learners passed this item in the UPFY group, only 27% thought they understood the meaning of this word. This implies that respondents might have been guessing when they were answering Section B or that the respondents were not confident about their semantic knowledge regarding the word "function". What is also interesting is that 67% of the UPFY staff expected the learners to know the meaning of the word, while in fact, 78% of the respondents knew the meaning of the word. In almost all other cases, the lecturers' expectations were higher than the respondents' actual knowledge. The lecturers might have felt that because the meaning of "function" as it is used the Physics classroom (a mathematical relation) is so far removed from the meaning in everyday use (purpose or job) that many learners might misunderstand the word. In fact, it might be for the very reason that the "science" and "lay" meanings are so distinctly different from each other that learners understand the meaning of the word in context. In other words, even though the lay meaning of the word "function" and the Physics meaning of the word "function" look the same, they are as distinct from each other as a river "bank" and a financial institution type of "bank".

Figure 4.6: Responses and expectations for the word "function"

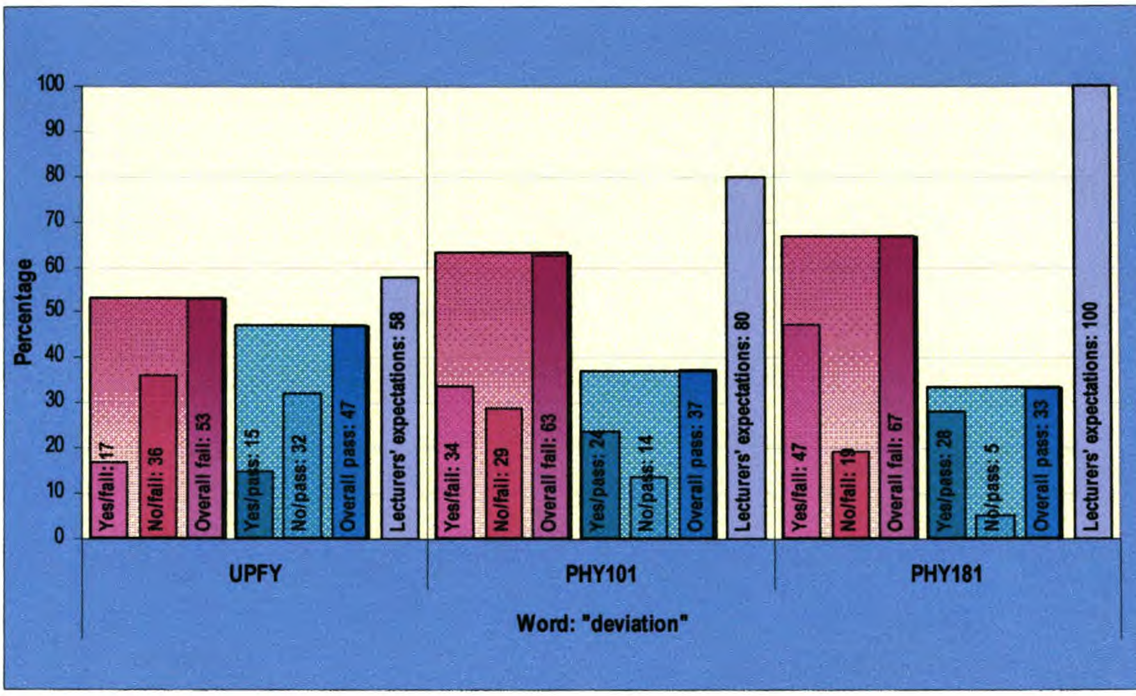


4.3.3.4 "Deviation"

What is interesting about the results for "deviation" was that the UPFY group did considerably better that the two PHY groups; UPFY respondents scored 47%, while the PHY 101 group scored 37% and the PHY 181 group only 33% (see Figure 4.7). It could be that the UPFY lecturers explained the meaning of the word to their learners, in which case one wonders why more than half the group still did not understand the word' meaning adequately to pass the test.

What is also of interest is that the PHY lecturer expected very high levels of understanding of the two PHY groups, namely 80% and 100%, while the UPFY lecturers were very much more realistic in their expectation (58%). "Deviation" is definitely a word which would need to be explained by lecturers in the three Physics courses targeted in this study in order to achieve a better overall understanding of class material.

Figure 4.7: Responses and expectations for the word "deviation"



4.3.3.5 "Normal"

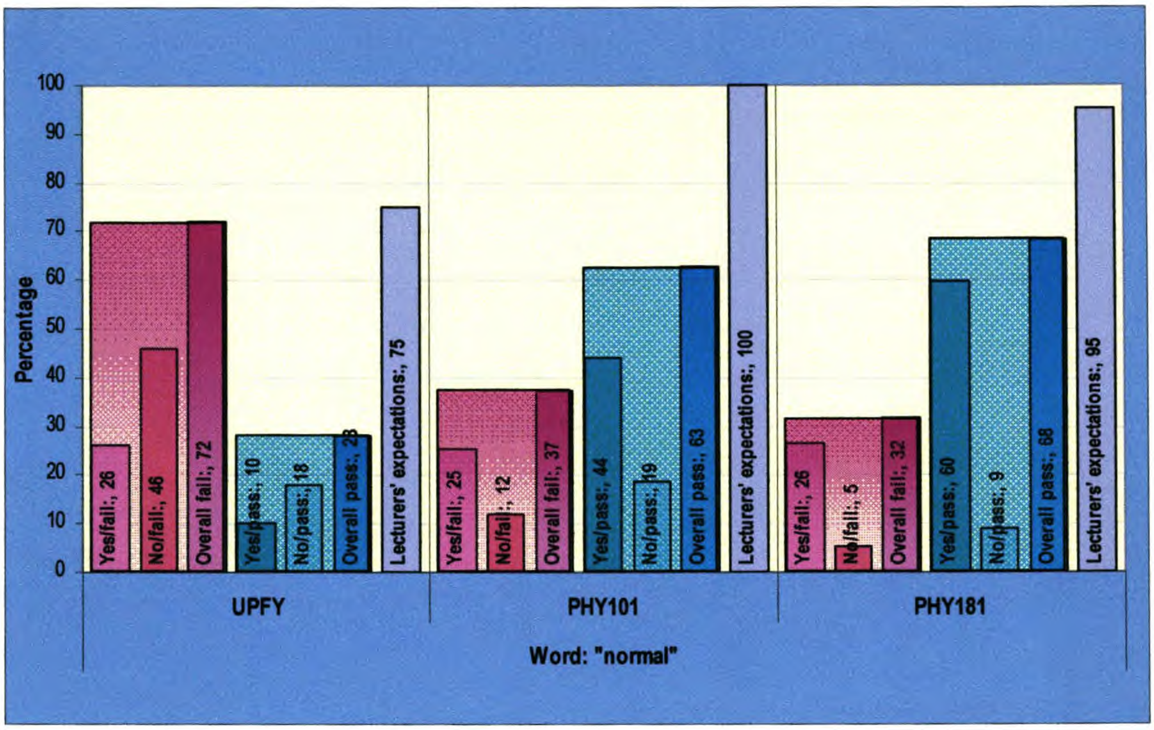
The pass rate for "normal" in the pilot study was 35%. The responses for the word "normal" indicated that this was the least problematic word for the respondents in the pilot study. By contrast, only ten percent of the UPFY respondents who thought they knew the meaning of "normal" were correct (see Figure 4.8). Only 28% of the UPFY respondents passed this item, while the lecturers expected 75% of the UPFY learners to know the meaning. The two PHY groups scored higher on this item: 63% and 68% for the PHY 101 and PHY 181 groups respectively. Despite the fact that they might have scored higher than the UPFY learners on this item, their score was still roughly 30% below the lecturer's expectations.

It is of concern that the UPFY learners in particular scored so poorly on this item. The lay meaning of "normal" (usual) is distinctly different from the Physics meaning (perpendicular to). One would think that learners would soon realise that the lay meaning they have at their disposal could not possibly be correct within the context in which they hear the word being used in the Physics classroom. According to Lewis (1990:13),

> ... the dominant sense of any word lies uppermost in our minds. Wherever we meet the word, our natural impulse will be to give it that sense. When this operation results in nonsense, of course, we see our mistake and try over again. But if it makes

tolerable sense our tendency is to go merrily on. We are often deceived. … I call such senses dangerous sense because they lure us into misreading.

Figure 4.8: Responses and expectations for the word "normal"



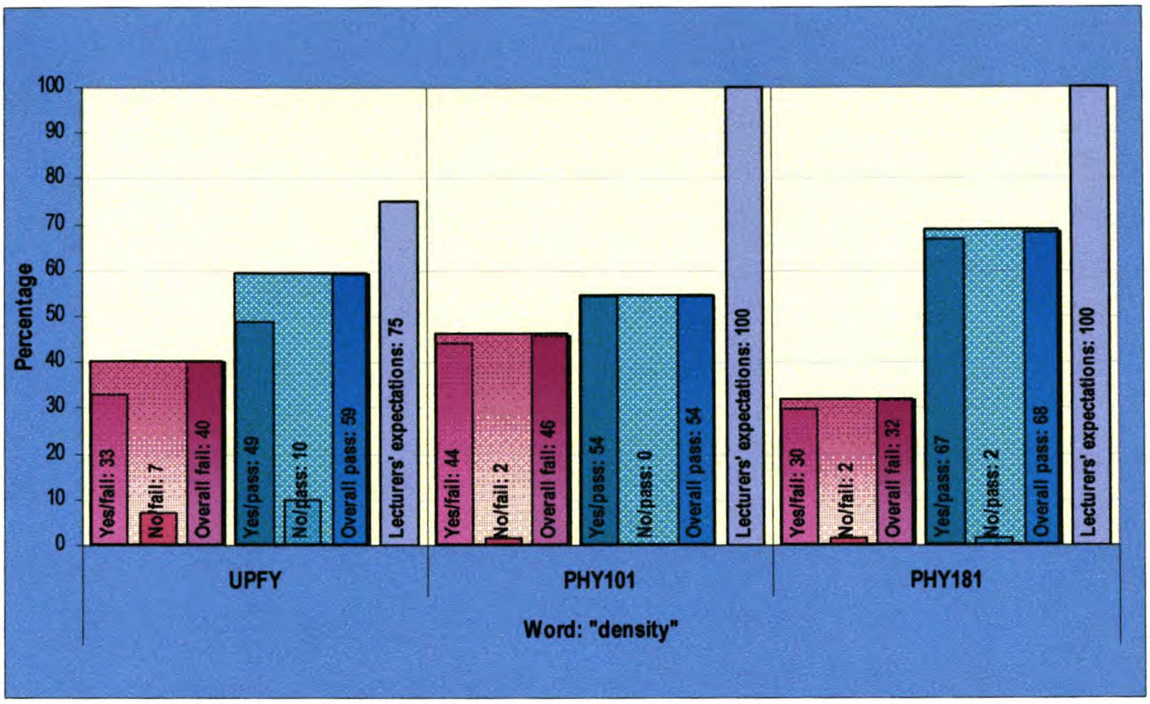
A Physics learner who, by the beginning of the second semester, has not realised that the "uppermost" meaning of "normal" does not make sense in the context of the Physics material will be at a great disadvantage in the classroom. The UPFY lecturers therefore need to address the learners' knowledge of this word in particular.

4.3.3.6 "Density"

The scores for the word "density" are not particularly exceptional. In this case, as in many others, the lecturers expected more learners to understand the word than actually did (see Figure 4.9).

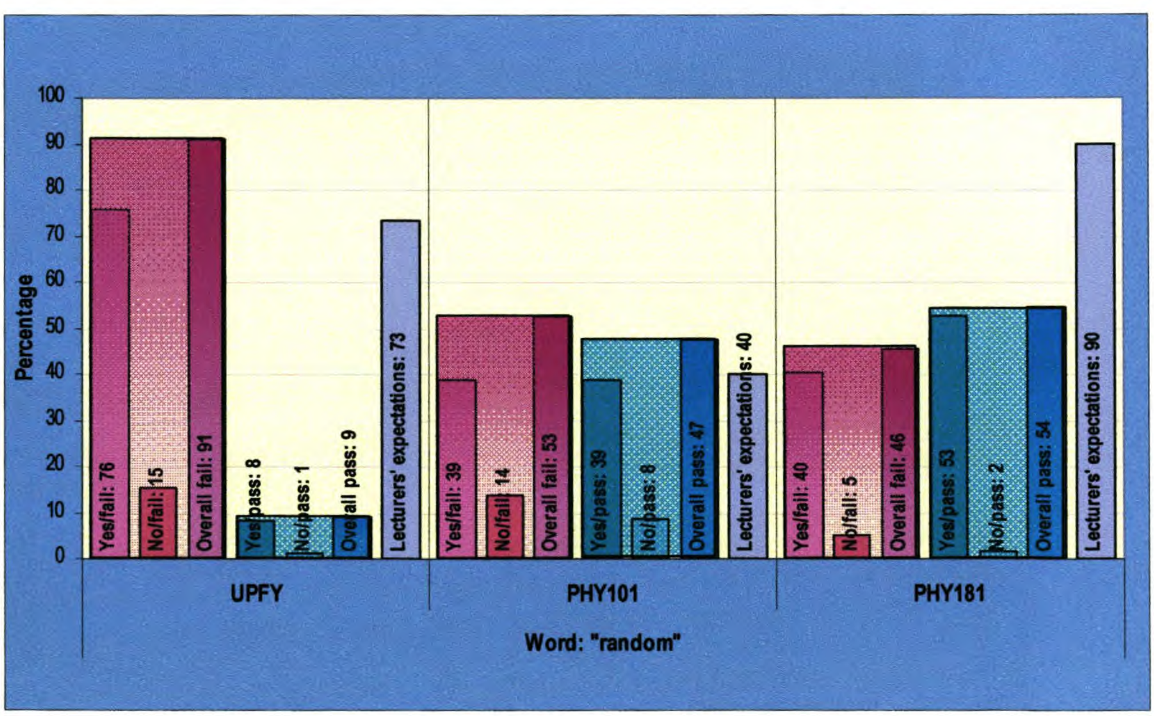
In addition, the respondents themselves had a higher expectation of themselves than their actual achievement reflected. The lecturer of the PHY 101 and PHY 181 groups was very confident that his learners knew the meaning of this word, however, in the case of the PHY 101 respondents, only 54% knew the meanings, while only 68% of the PHY 181 respondents knew the meaning of this word.

Figure 4.9: Responses and expectations for the word "density"



4.3.3.7 "Random"

Figure 4.10: Responses and expectations for the word "random"



It is of grave concern that 91% of the UPFY group failed this item (see Figure 4.10). Most respondents in this group (76%) thought they understood the meaning of the word, while only 9% actually did. The learners' knowledge of this word needs immediate remediation in the UPFY group.

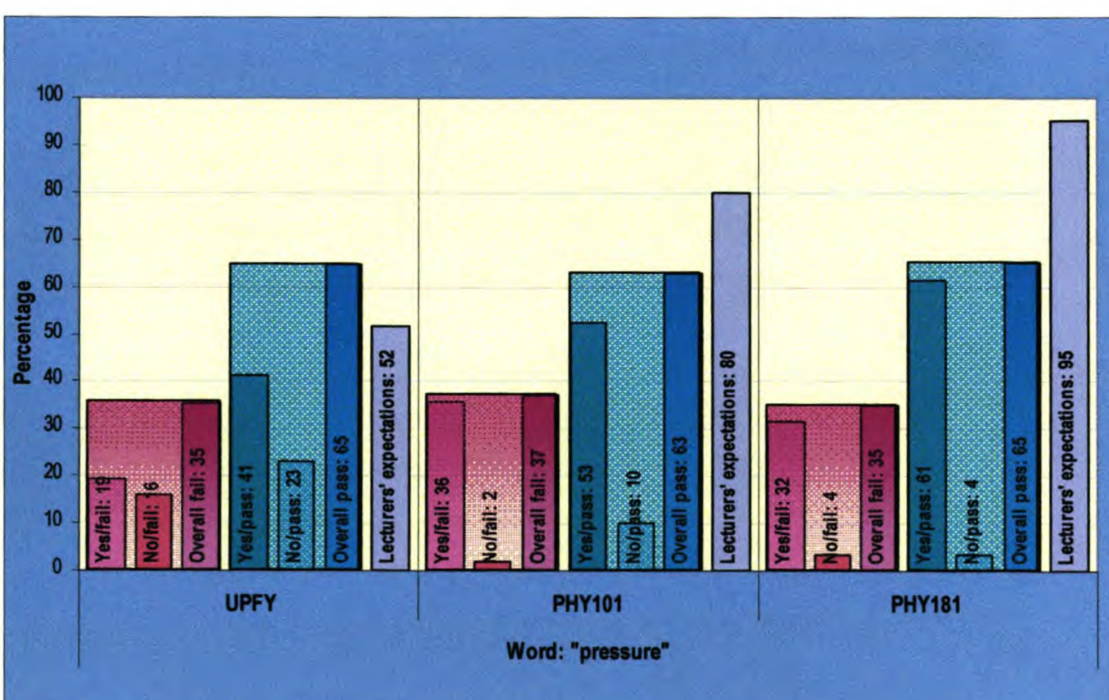
It is also interesting to note that the PHY 101 lecturer expected only a 40% pass rate. More respondents than expected passed this item in the PHY 101 group. One wonders why the PHY 101 lecturer had such a particularly low expectation of this group for this word.

4.3.3.8 "Pressure"

Once again the lecturers' expectations for the PHY 101 and PHY 181 group were disappointed. Although respondents in the two PHY groups scored 63% and 65%, the lecturer actually expected 80% and 95% levels of knowledge. The three UPFY lecturers, on the other hand, were also inaccurate with their expectation, in that more respondents passed this item than they expected (65% passed, as opposed to the expected 52%).

It is interesting that the UPFY group did as well as the PHY 181 group (both achieved 65%) and better than the PHY 101 group, which scored 63%. The UPFY learners are generally regarded as not being as academically strong as other learners on campus, since they are Foundation Year learners and were not selected to first-year mainstream courses on the basis of academic merit. This item shows that the UPFY learners are not weaker than the two PHY groups in all cases, as many staff members might believe.

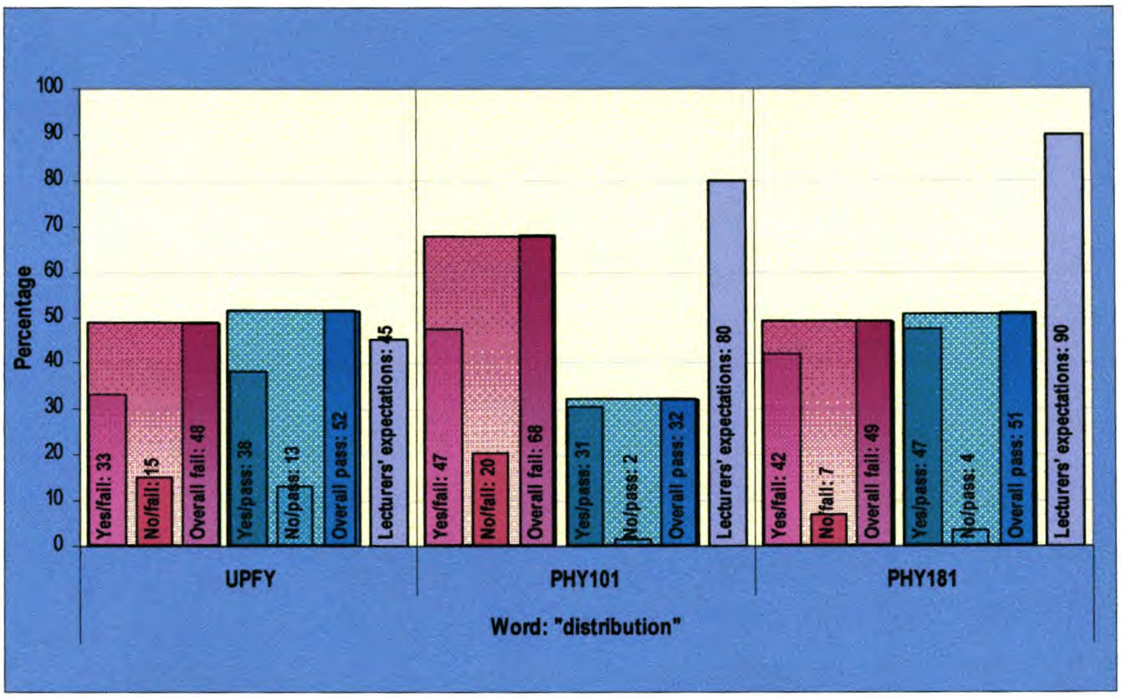
Figure 4.11: Responses and expectations for the word "pressure"



4.3.3.9 "Distribution"

"Distribution" is another word where the UPFY respondents scored higher than their lecturers expected they would (see Figure 4.12).

Figure 4.12: Responses and expectations for the word "distribution"

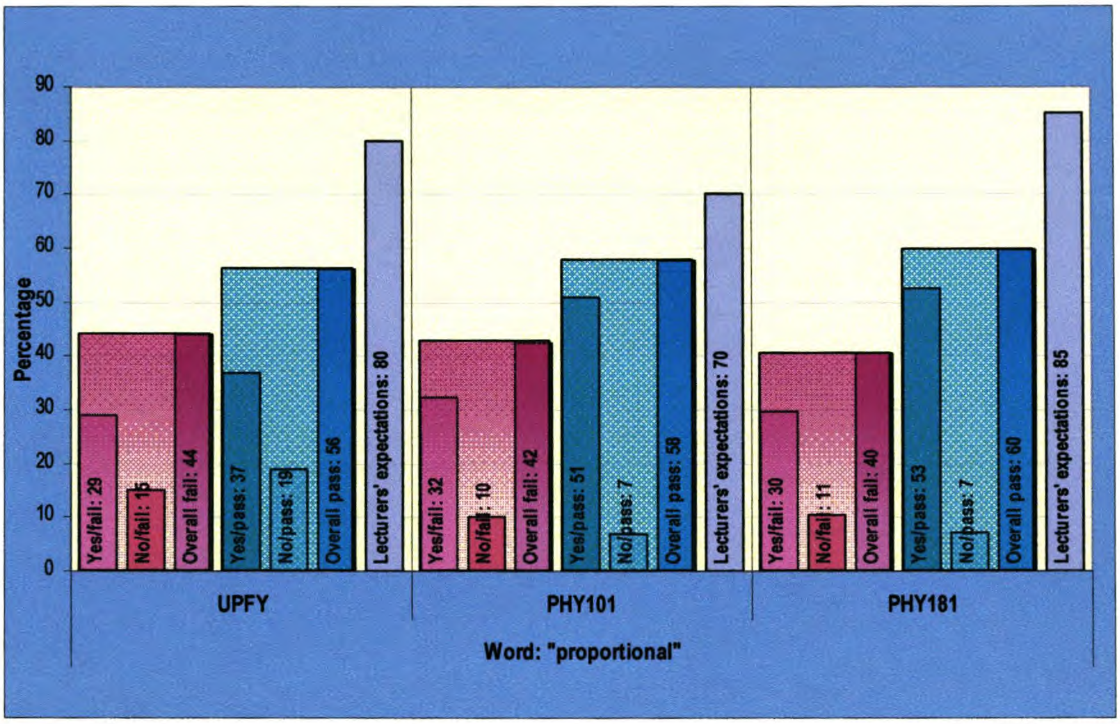


Again the respondents in the three groups overestimated their abilities. The confidence of the PHY lecturer in the respondents' knowledge was completely unrealistic; he expected 80% of PHY 101 respondents to pass, while only 32% passed, and he expected 90% of PHY 181 respondents to pass while only 51% passed. Similar to the results for "pressure", UPFY respondents exceeded the expectations of their lecturers on this item. Not only did the UPFY group exceed their lecturers' expectations, but UPFY respondents also achieved higher scores (52%) than the two PHY groups (45% and 51%).

4.3.3.10 "Proportional"

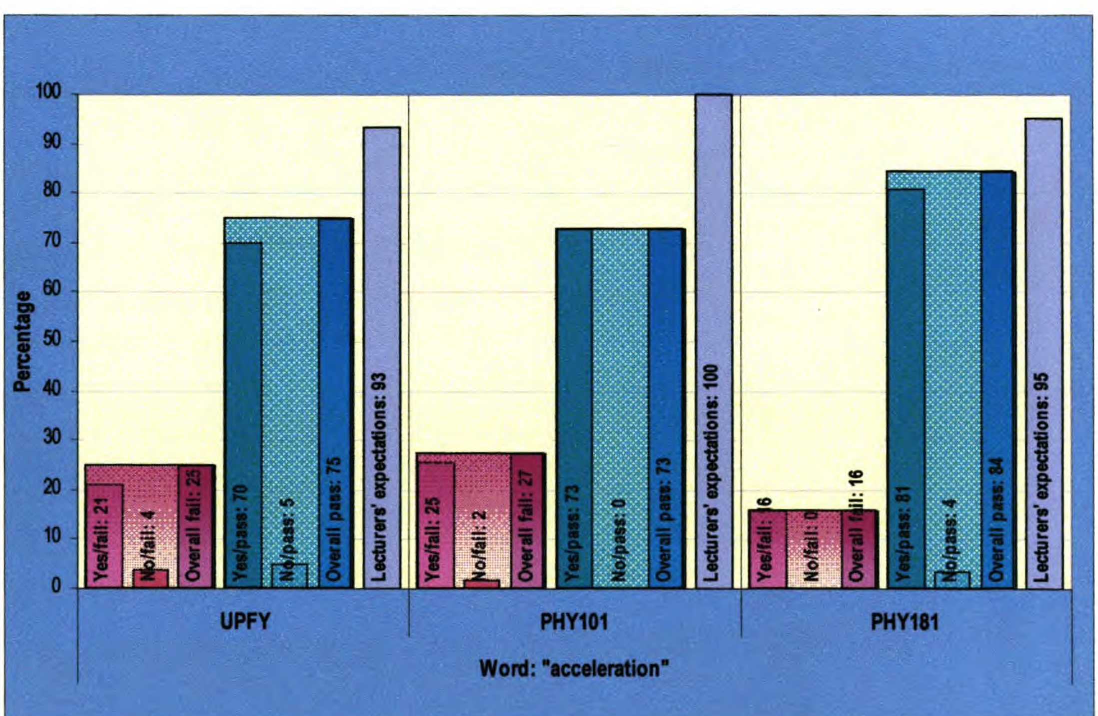
For the term "proportional" the lecturers of all three groups had greater expectations of the respondents than the respondents had of themselves or than the respondents' actual knowledge (see Figure 4.13). The pass rate for all three groups was in the 56% to 60% range, higher than the pass marks for many other words, but far lower than should be the case for a fundamental term used in the Physics classroom. The staff expectations fell in the range of 70% to 85%, while the respondents' expectations were 66% ("yes/fail" plus "yes/pass") for the UPFY group and 83% for both PHY groups.

Figure 4.13: Responses and expectations for the word "proportional".



4.3.3.11 "Acceleration"

Figure 4.14: Responses and expectations for the word "acceleration"

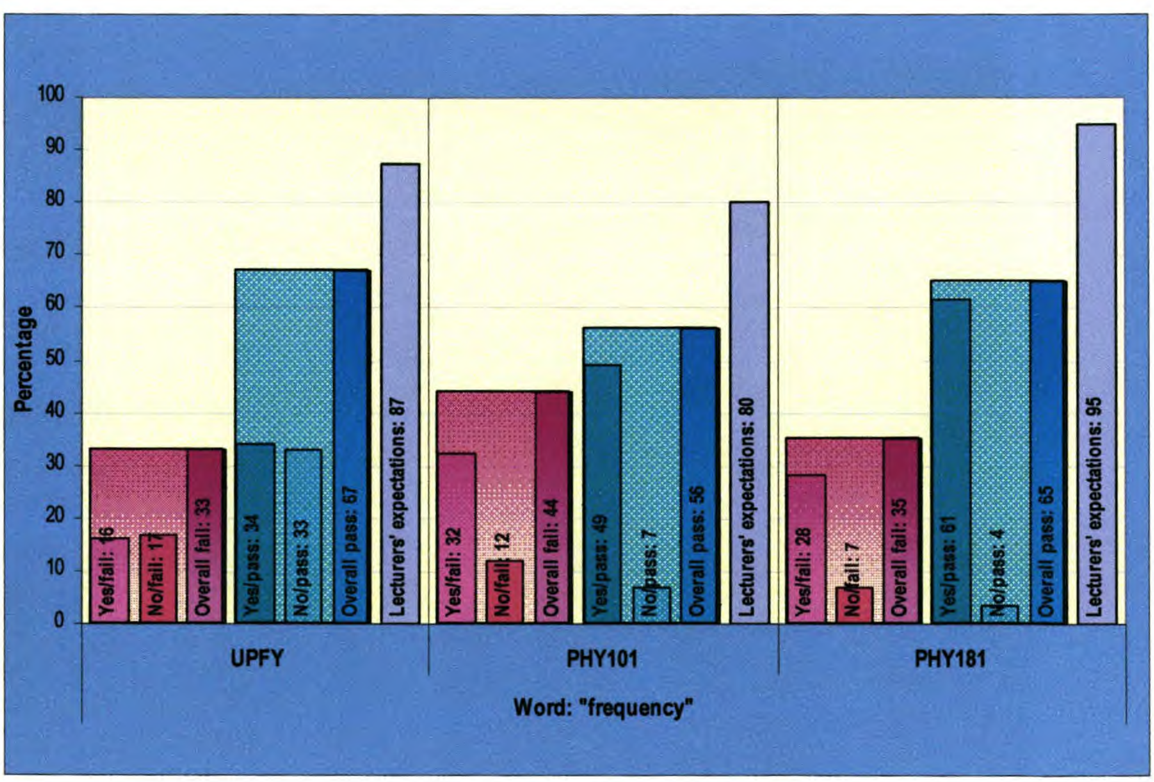


Respondents seemed to be justifiably confident in their knowledge of the meaning of "acceleration". Their confidence levels fell within the range 70% to 81%, as evidenced in the "yes/pass" column of Figure 4.13. The lecturers expected a high score on the test (between 93% and 100%), and although the respondents' actual knowledge did not reach these high levels, the respondents did comparatively well on this item, with the actual pass scores falling in the range from 73% to 84%. All three groups scored best on this item.

4.3.3.12 "Frequency"

UPFY respondents were not very confident about the term "frequency". Only 50% of UPFY learners (those in the categories "yes/fail" and "yes/pass") claimed to understand the meaning of "frequency", as opposed to 81% of the PHY 101 and 89% of the PHY 181 respondents (see Figure 4.15). Even though they were the least confident of the three groups, the UPFY learners achieved a higher score on this word (67%), than did the other two classes (56% and 65%). In all three cases, the lecturers expected the respondents to do better. The large gap of 30% between the lecturer's expectation (95%) and the actual achievement of the PHY 181 group (65%) is a matter of concern.

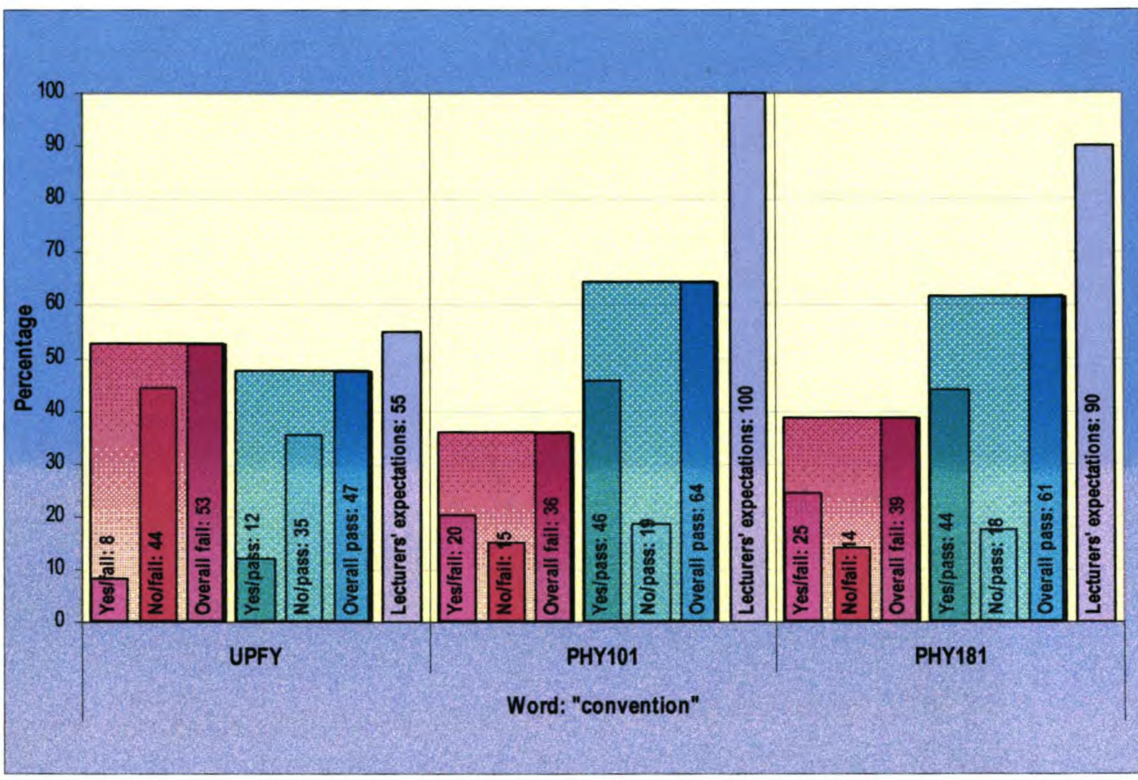
Figure 4.15: Responses and expectations for the word "frequency"



4.3.3.13 "Convention"

There was a reasonably close match between the lecturers' expectations and the actual results for the word "convention" in the case of the UPFY respondents (see Figure 4.16). In the two PHY classes, however, there was a very large gap between the lecturer's expectation and the respondents' achievement: a 36% gap in the case of the PHY 101 group and a 29% gap in the case of the PHY 181 group. The gap between expectation and reality must be brought to the attention of the PHY lecturers.

Figure 4.16: Responses and expectations for the word "convention"



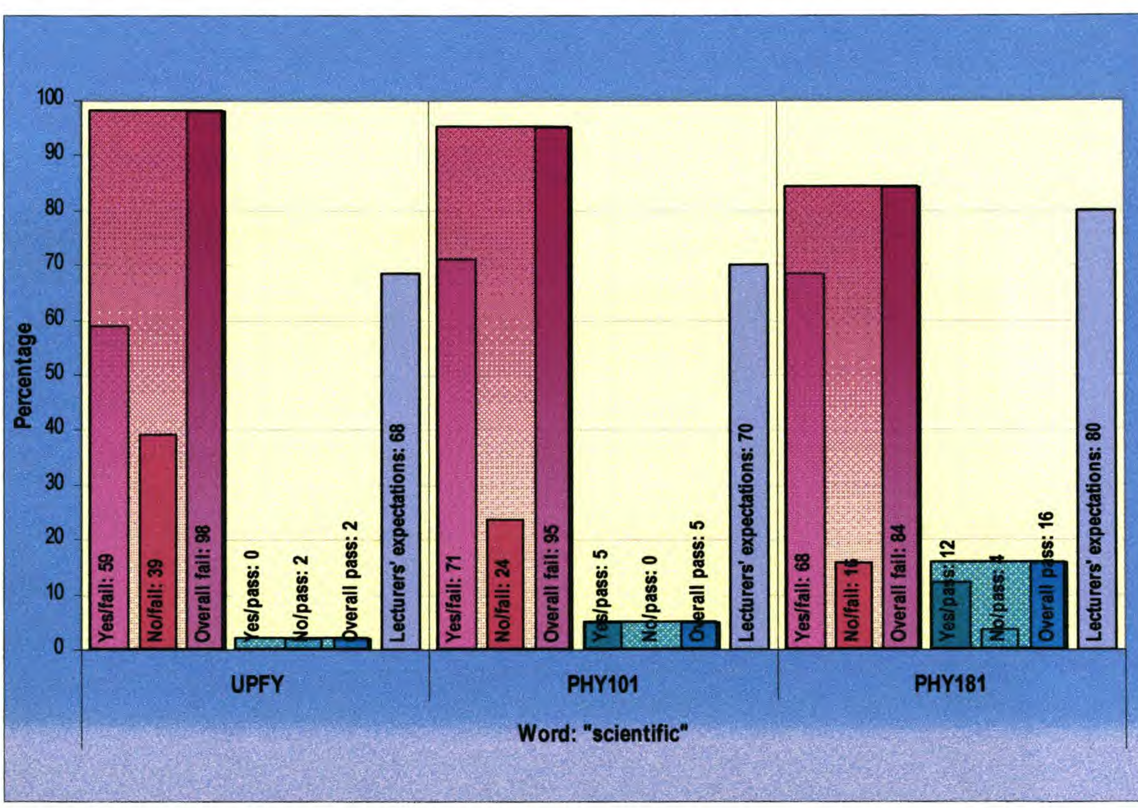
Even though the lecturers' expectation of the UPFY group was more realistic at 55%, the pass rate for this word was only 47% for the UPFY respondents. The learners' knowledge of this word therefore also needs remediation in the UPFY group.

4.3.3.14 "Scientific"

The results for the word "scientific" were remarkable. It is clear from Figure 4.17 that the overall fail rate for "scientific" was high: a 98% fail rate for UPFY respondents, 95% and 84% for the PHY 101 and 181 groups respectively. None of the UPFY respondents who said they understood this word actually passed the test on this item.

This word also had the highest failure rate in the pilot study (see Figure 4.2). The failure rate in the pilot study was 98%. An explanation for this high failure rate was investigated in the pilot study by examining the options given in Section B of the test. It was speculated that the respondents might have read the word "scientific" in isolation from the rest of the sentence. An examination of the individual responses to this item in the pilot study showed that the word with the highest incidence of incorrect responses was the option "objective" (76% incorrect). This seems to indicate that the respondents understood the instruction to regard the word in the context of the sentence correctly and that not only is "scientific" a problematic word, but that the four options are also problematic. Regarding the remaining options for this word, the option "systematic" was indicated incorrectly by 61% of the respondents, "accurate" was indicated incorrectly by 63% and "experimental" was indicated incorrectly by 56% of respondents.

Figure 4.17: Responses and expectations for the word "scientific"



In the main study, the words "objective", "systematic" and "experimental" were used in Section B and the sentence was grammatically simplified. Despite these changes in the question, the results were very similar to those of the pilot study: by far the majority of the learners failed this item. The responses received and analysis of the words given in Section B point to learners' experiencing difficulty in understanding "scientific" and also other words often used within a scientific context such as "experimental", "objective", "accurate" and "systematic".

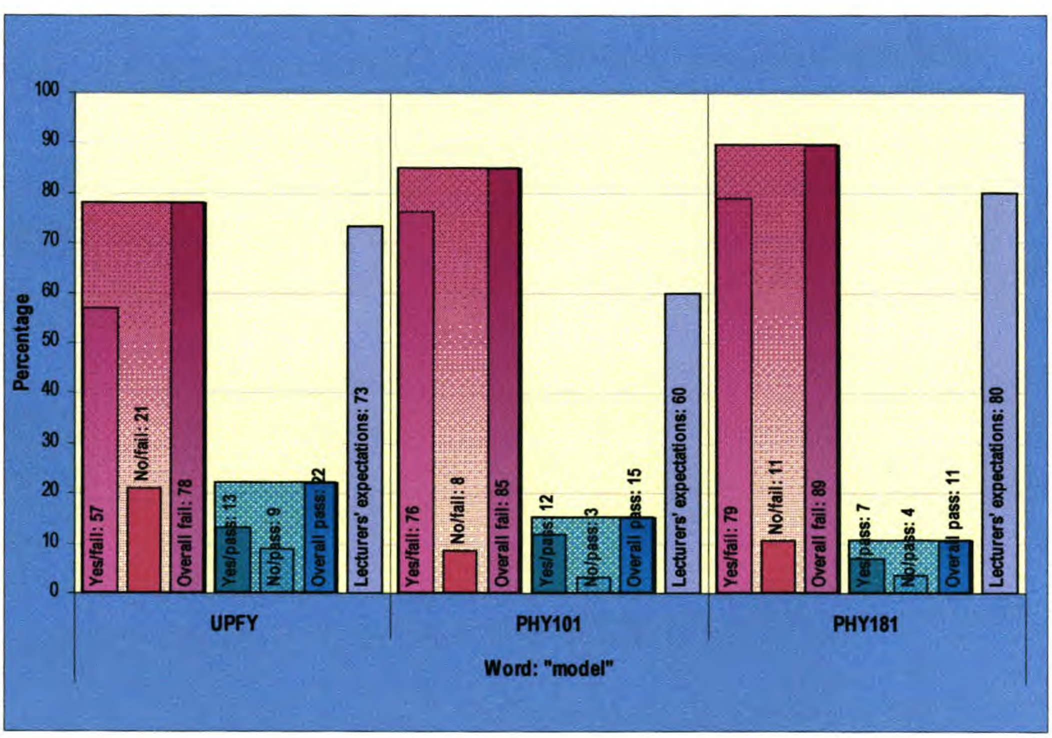
4.3.3.15"Model"

The failure rate for "model" was also high: 78% of the UPFY respondents failed this item, 85% of the PHY 101 respondents and 89% of the PHY 181 respondents failed this item in the tests of actual knowledge (see Figure 4.18).

There was a larger discrepancy between the lecturers' expectations and the actual knowledge respondents had: UPFY lecturers expected a knowledge level of 73%, while only 22% of the respondents passed, the PHY 101 lecturer expected 60% of learners to pass, while only 15% of the PHY 101 group passed and the lecturer expected 80% of PHY 181 learners to pass while only 11% of the PHY 181 respondents actually did pass.

In this item the UPFY respondents achieved a higher score than those in the two PHY courses: 22% as opposed to 15% and 11%. Despite the fact that the UPFY respondents achieved higher scores on this word, the knowledge of all respondents for this word was very poor and should be remedied immediately. Many Physics concepts are based on models, and learners who lack an idea of what a model is will probably have problems with understanding a concept such as the atomic model and its development over time.

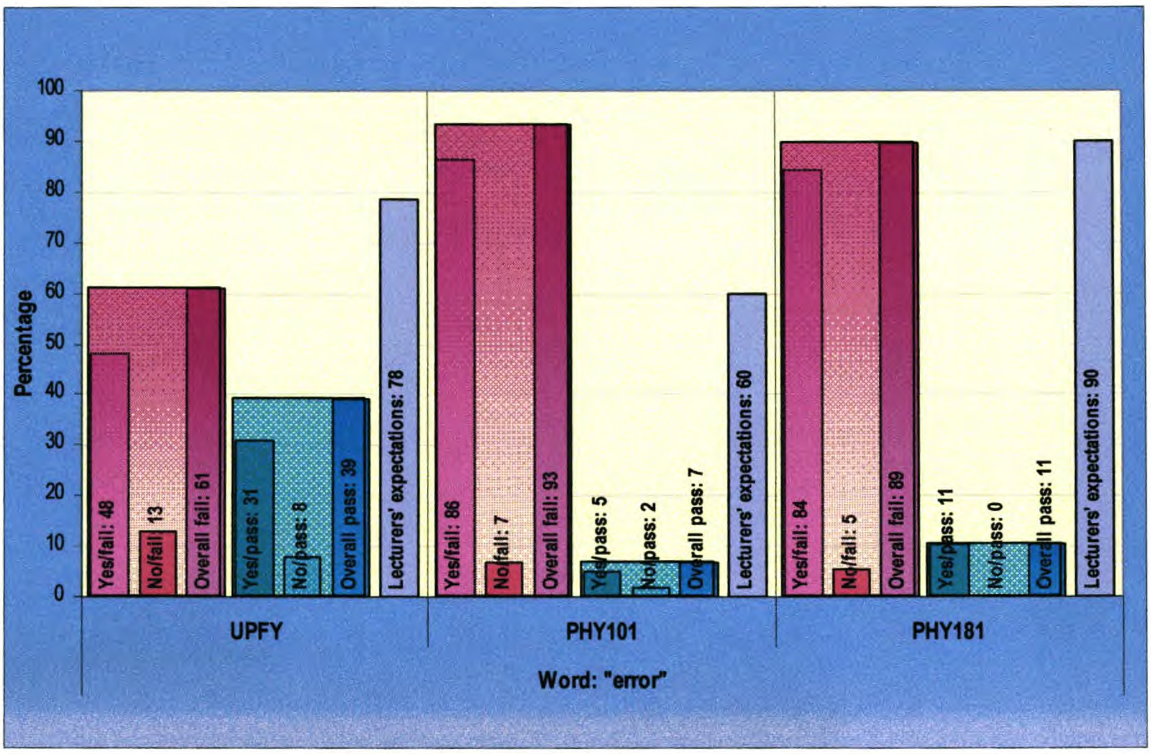
Figure 4.18: Responses and expectations for the word "model"



4.3.3.16 "Error"

The UPFY respondents fared much better on this item than did the two PHY classes (see Figure 4.19). UPFY respondents achieved a pass rate of 39%, as opposed to the PHY 101 group's pass rate of 7% and the PHY 181 group's pass rate of 11%.

Figure 4.19: Responses and expectations for the word "error"



A reason for this large discrepancy between the UPFY and two PHY groups could be that some time in the UPFY curriculum is spent on the scientific method at the beginning of the year, focusing on the difference between a measuring error and a measuring mistake. The UPFY learners were therefore explicitly taught the meaning of the word. Despite the specific teaching of the meaning of the term, 61% of the UPFY respondents still misunderstood the meaning of "error" in the test. The UPFY lecturers should therefore strongly consider revising the section dealing with errors and mistakes. It would appear that the PHY learners' knowledge needs immediate remediation.

4.3.3.17 Conclusion of semantic knowledge and expectations

From the above discussion of the scores achieved on the knowledge test by the three groups it is clear that all three groups had problems in understanding most of the 16 terms which were investigated. Regarding this study in particular, it is to be recommended that the lecturers of all three groups examine the test results below and consider remedial action. More general recommendations appear in Chapter 5.

Table 4.3: Ranked summary of scores achieved on the vocabulary knowledge test

UPFY	Overall fail	PHY 101	Overall fail	PHY 181	Overall fail
scientific	98.00	scientific	94.91	model	89.47
random	90.90	error	93.21	error	89.47
model	78.00	model	84.74	scientific	84.21
normal	72.00	distribution	67.79	deviation	66.66
error	61.00	deviation	62.71	phenomenon	49.12
phenomenon	56.00	random	52.53	distribution	49.12
observations	56.00	density	45.76	observations	45.61
deviation	53.00	frequency	44.06	random	45.61
convention	52.52	phenomenon	42.37	proportional	40.34
distribution	48.48	observations	42.37	convention	38.60
proportional	44.00	proportional	42.36	pressure	35.09
density	40.00	normal	37.28	frequency	35.08
pressure	35.35	pressure	37.28	normal	31.58
frequency	33.00	convention	35.59	density	31.57
acceleration	25.00	function	30.51	function	17.55
function	22.00	acceleration	27.11	acceleration	15.79
Average	**54.08**		**52.54**		**47.8**

4.3.4 Discussion of the open-ended answers for "scientific"

The term "scientific" was selected for an analysis of the open-ended answers (the answers given by respondents in Section C of the questionnaire) because the test results for the word were so poor. The open-ended answers of the UPFY and PHY 181 learners were categorised into concepts which the learners related to the word "scientific". PHY 101 respondents did not complete this section, due to time constraints.

As can be seen in Table 4.4, of the UPFY respondents 56% gave a circular definition of the word "scientific" by stating that it had something to do with "science". Only 5% were able to give a definition related to the scientific method and mentioned characteristics of the scientific method, such as "observation", "prediction" and "drawing conclusions". Many PHY 181 respondents (40%) thought "scientific" had to do with "experiment", in fact, many seemed to think that "scientific" and "experimental" were interchangeable. Although many learners explained "scientific" in terms of words such as "systematic", "objective", "facts", "accuracy", "calculation", "observation", "proof" and "model" or "theory", very few (only 5% of the UPFY respondents and 7% of the PHY 181 respondents) described "scientific" as a combination of some of the aforementioned concepts.

It seems clear when examining the open-ended explanations given for the word "scientific" that respondents either could not define it at all (it has to do with "science") or provided a uni-dimensional superficial meaning for the word. According to Dekkers (2004:1), the Department of Education's new curricula documents express the argument that a person who is "scientifically literate" has an understanding of the facts, theories and laws of science and also has skills associated with the development of scientific knowledge. If first-year learners do not seem to understand the word "scientific", it is questionable, whether they are in a position to understand the "nature of science" or what Dekkers (2004:1) describes as being the "cultural, political, historical, economic and societal role" of science.

Table 4.4: Categorisation of learners' definitions of "scientific"

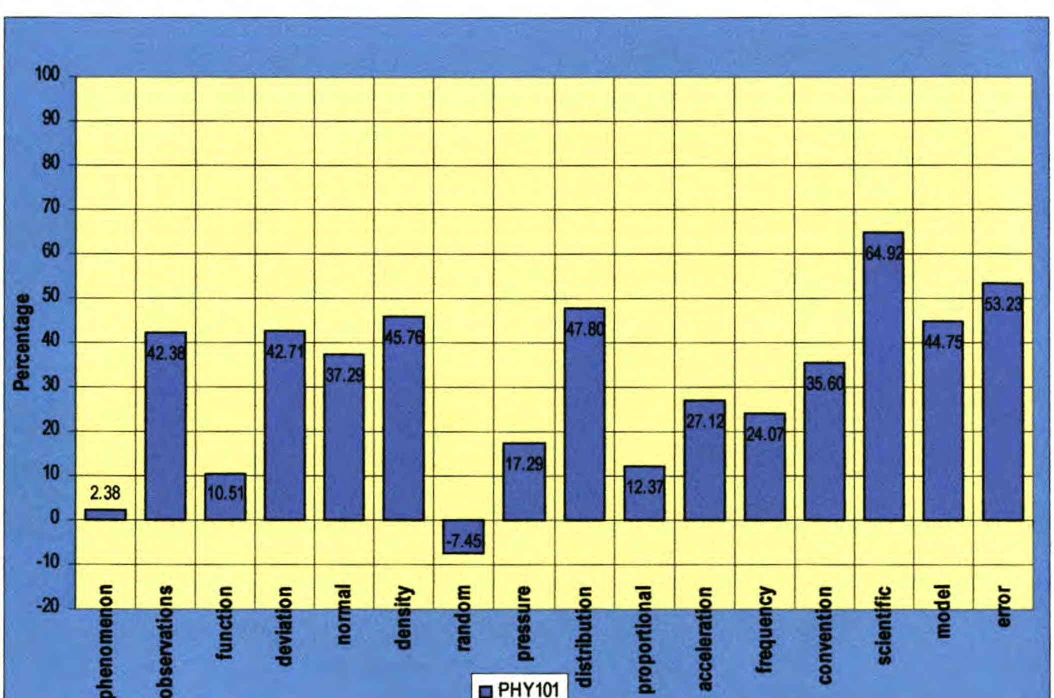
"Scientific" is related to:	**UPFY (%)**	**PHY 181 (%)**
Science	56	21.05
Experiment	7	40.35
Logic	4	0
Objective	2	3.50
Systematic	1	8.77
Facts	2	3.50
Accurate	2	0
Calculation	4	3.50
Observation	2	3.50
Proof	3	0
Objective and systematic	0	7.01
Model / theory	3	7.01
Thinking	4	0
Scientific method (observation, prediction, systematic, conclusion)	5	0
Senseless response	5	0
Total	**100**	**100**

4.3.5 Lecturers' expectations and learners' knowledge

The three tables below illustrate the differences between the lecturers' expectations and the respondents' knowledge. In Figure 4.20, which summarises the discrepancy between expectations and knowledge for the PHY 101 group, it is clear that there are five words ("phenomenon", "function", "random", "pressure" and "proportional") where there was less than a 20% difference between the lecturers' expectations and the respondents tested knowledge. As can be seen in Figure 4.21, which shows the difference between the PHY 181 lecturer's expectations and the PHY 181 respondents' knowledge of the tested words, in all 16 words, the lecturer expected a higher level of knowledge from the learners than the test results showed. "Deviation", "scientific", "model" and "error" are all words which the lecturer assumed the learners to understand much better than they do. There are only two words where there is a discrepancy of less than 20% between the lecturers' expectations and the respondents' knowledge.

Figure 4.22 shows that the UPFY lecturers' expectations were slightly closer to the respondents' actual knowledge than in the case of the PHY 101 and 181 classes. In three cases (the words "function", "pressure" and "distribution") the respondents actually showed a higher level of knowledge than the lecturers' expected. There are eight words in which the discrepancy is less than 20%.

Figure 4.20: Differences between the lecturer's expectations and the PHY 101 respondents' knowledge



When all the scores were added together, there was a larger difference between the lecturer's expectations and the respondents' knowledge in the PHY 181 group (638) than in the PHY 101 group (508) or in the UPFY group (472). The UPFY lecturers therefore had a more realistic expectation of the learner's knowledge than the PHY lecturer did. However, there remains a large difference between lecturers' expectations and respondents' knowledge in all three groups. In other words, lecturers think learners understand the vocabulary used in the classroom much better than learners actually do understand the vocabulary.

Figure 4.21: Differences between the lecturer's expectations and the PHY 181 respondents' knowledge

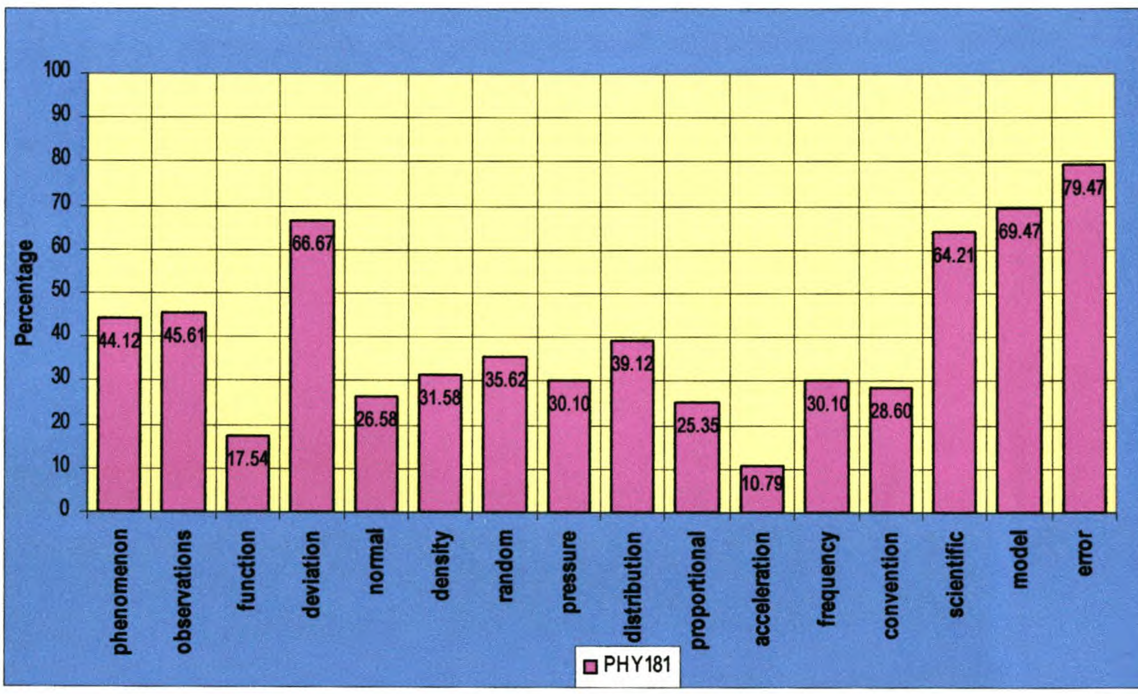
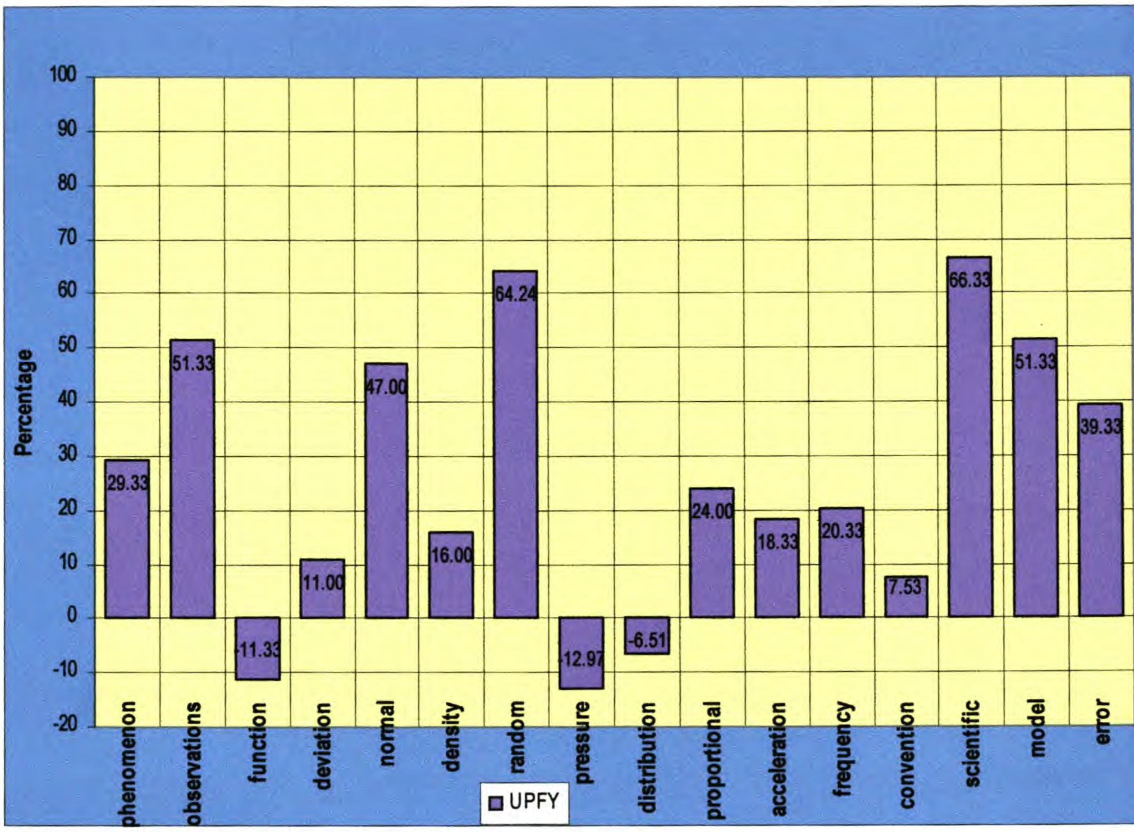


Figure 4.22: Differences between the lecturers' expectations and the UPFY respondents' knowledge



4.4 Conclusion

The results show that there was a wide range of responses and that learners' and lecturers' expectations did not reflect the reality in terms of learners' actual knowledge. In most cases the results showed a significant gap between perception and reality.

The data appears to indicate that there is a difference between expectations and reality. On the one hand, it is important to show both learners and lecturers that the learners do not understand the word "random", for example, and that it is unrealistic for the lecturer to expect such an understanding. On the other hand, it is very important to indicate to both groups the need to establish proper communication in the classroom to determine the levels of understanding and to modify levels of expectations. In this way there can be more successful communication and, consequently, better education.

Learners in the three groups tested at the University of Pretoria for the main study clearly had problems regarding their knowledge of terminology used in the Science classroom. A serious disadvantage such as not understanding the basic language of a subject must have a profound impact on the learners' understanding, interpretation and application of knowledge. Chapter 5 discusses specific recommendations and strategies for staff to assist learners with regard to vocabulary development.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

It is clear that there is a "gap" between lecturers' knowledge and use of vocabulary and learners' knowledge and use of vocabulary. Both lecturers and learners make a number of assumptions about learners' knowledge of the vocabulary used by lecturers and learners. This chapter attempts to summarise the findings relevant to the objectives posed in Chapter 1 and highlights the issues of such assumptions arising from the gap between lecturers' and learners' perceptions. Some recommendations from the literature are discussed and suggestions emerging from the results of this study are made regarding possible ways to improve learner-lecturer communication.

5.2 Findings

5.2.1 Objectives

The answers to the research questions (formulated under "Objectives" in Section 1.2.2) have been fully discussed in Chapter 4, but a brief summary of the answers is given here.

5.2.1.1 What is the learners' perceived level of knowledge of selected scientific words?

On the whole, learners thought they understood the words tested 74.98% of the time.

5.2.1.2 What is the learners' actual level of knowledge of the words?

In the main study, the respondents failed the "test" 51.47% of the time.

5.2.1.3 What is the learners' actual level of knowledge compared to the level of knowledge expected by the lecturers?

The answer to this question can be set out in a table to highlight the differences between the UPFY group, the PHY 101 group and the PHY 181 group. As can be seen in Table 5.1 in all cases the UPFY respondents' scores are the lowest, followed by those of the PHY 101 respondents, which, in turn, are followed by those of the PHY 181 respondents.

Table 5.1 Summary of learners' expectations, lecturers' expectations and actual scores on the vocabulary knowledge test.

Group	Learners' expectations	Lecturers' expectations	Average of actual scores on the vocabulary knowledge test
UPFY	60%	72%	46%
PHY 101	79%	78%	47%
PHY 181	85%	93%	52%

5.2.1.4 What meanings do learners associate with certain words?

The word "scientific" was investigated and it was found that the respondents' understanding of this word was very narrow and did not encompass the broad principles of what it means to be "scientific". So, for example, respondents tended to see the word "scientific" as meaning "accurate" or "experimental" or "objective" or "theoretical", but not all of these concepts at the same time.

5.2.1.5 What is the learners' level of understanding of the words compared to their final marks in Physics?

There was a low positive correlation between the respondents' understanding of the words and the respondents' final Physics course marks.

5.2.1.6 What is the learners' level of understanding of the words compared to their achievement in the vocabulary section of a language proficiency test?

There was a low positive correlation between the respondents' understanding of the words and the scores they achieved in the vocabulary section of the language proficiency test.

5.2.1.7 What is the learners' level of understanding of the words compared to their overall results in the language proficiency test?

There was a low positive correlation between the understanding of the words and the scores achieved on the language proficiency test as a whole.

5.2.1.8 What is the learners' level of understanding of the words compared to their final English proficiency course marks?

There was a low positive correlation between the understanding of the words and the scores achieved in the English language proficiency courses.

In addition to the answers to the above research questions, there seemed to be two main issues which need elaboration: learners' and lecturers' making assumptions about knowledge and the knowledge gap between lecturers and learners.

5.2.2 Assumptions made by lecturers and learners

This study supports the findings of Schunk (2000:265), who asserts that "[s]peakers make assumptions about what listeners know", and of Touger (1991 in Moji 1998:16), who argues that "concepts and the language that conveys them may be evident to a physicist or to a teacher but not to a student". The lecturers in this study assumed that the learners understood the vocabulary, in some cases, 100% of the time.

The lecturers' assumption may be caused by what Fiske (1989:832) suggests to be a misinterpretation of words "caused by the fact that [lecturers and learners] often do not recognise that they [the words] are there at all. Because they are so deeply embedded in our culture, they appear 'natural', as though there were no alternatives". Many lecturers at university would not even consider stopping to explain that a word such as "scientific" has a complex meaning and that many aspects of being "scientific" might apply at the same time, while all aspects do not necessarily apply all the time. Many lecturers would not consider it necessary to explain what "scientific" means because, to the lecturer, the meaning appears "natural".

It has become clear in this research that both lecturers and learners make assumptions about the words they think they know and the words they think others understand.

5.2.3 General and language knowledge "gaps"

Walker (1996:5) gives an excellent description of what could be described as the knowledge gap between the inhabitants of "Worlds two and three" (lecturers and researchers) and the inhabitants of "World one" (learners) as discussed in Chapter 2:

> We all bemoan our students' lack of knowledge of principles or concepts we are sure they have been taught, but how often do we do anything about it? Perhaps we should be less surprised than we are. I am sure, if we are honest with ourselves, we

> are aware that we only had an imperfect understanding of many of the key concepts of our discipline when we graduated. Certainly, when I first came into academic life after several years away from Chemical Engineering, I often found myself thinking "So that's what that was about" when having to teach a topic I had not looked at since finishing my degree. Over those first few years in lecturing, I became very aware of just how much I did not really understand properly, and it was only when faced with having to explain it to others that I really came to grips with many concepts. Is it any surprise then that many of our students have only an imperfect understanding of, and in some cases, downright misconceptions about many important principles?

Other researchers also highlight the gaps in language and general knowledge. Schunk (2000:264) mentions that understanding is more difficult when "more links are missing and when propositions are further apart". Wood (1994:169-170) suggests that "there is no such thing as a pure 'language problem' which is not at the same time a general knowledge problem" and Sutton (1981:215-216) discusses the way scientists have "codified" the language, and that the educator has to explain the metaphors to get to the heart of the concept.

It is clear from this study that there is a gap of understanding between lecturers and first-year or foundation year learners. This means that Science teachers have to be language teachers at the same time. The fact that Science teachers have chosen a scientific field rather than a language area to specialise in may mean that their language skills are not as strong as their science skills. It will be difficult to convince Science teachers that they need to teach language at the same time as science. Lecturers often complain about being overloaded with preparation, lecturing, marking, administrative duties and research. It might not be an easy task to convince lecturers to add another dimension to their daily tasks.

5.3 Recommendations

Recommendations from the literature generally fall into two categories: those researchers who assert that closing the gap between learners and lecturers is more a matter of time than teaching, and those who recommend active, structured intervention in order to narrow the gap in language expertise between learners and lecturers.

5.3.1 Unstructured approach to learning

According to Dembo (1988), Krashen argues that exposure to a language over time is the best way to learn the rules of that language. Furthermore, Krashen believes that teachers do not need to provide formal instruction in a language, but rather opportunities to hear the language being spoken.

Many researchers, such as Beal and Belgrad (1990 in Schunk 2000:263), Schunk (2000:210), Lave (1997:13), Lemke (1997 in Block 2002) and Eggen and Kauchak (1997:59) (mentioned in Chapter 2), agree that knowledge is constructed over time and that learners need time to learn new concepts. This lends weight to Cummins' argument (mentioned in Chapter 1) that while Basic Interpersonal Communication Skills (BICS) can be achieved within two years of immersion, a learners' Cognitive Academic Language Proficiency (CALP) may take five to seven years to develop to that of a first language speaker (Shoebottom 2001).

Some researchers assert that learning is vicarious, unstructured and informal, which, of course, much learning is. However, in order to overcome the enormous gap between "World one" users of language in the science classroom and "World two" users, it would appear that a more formal and structured approach should be followed.

5.3.2 Structured intervention

There are three kinds of strategy that researchers recommend to assist learners' assimilating the language of science: providing scaffolding, focusing on the design of the learning programme and adapting texts.

5.3.2.1 Scaffolding

Scaffolding, or a strategy which assists learners to move from less challenging to more challenging work, especially in terms of the language of the Science classroom, is recommended by Rosenshine and Meister (1992 in Eggen & Kauchak 1997) and Palincsar (1987 in Eggen & Kauchak 1997).

5.3.2.2 Design of the learning programme

Several authors, such as Eggen and Kauchak (1997), Inglis (1993 in Moji 1998:32), and Zeidler and Lederman (1989:777) recommend the structured design or adaptation of a learning programme and materials for the purposes of closing the so-called gap between lecturers and learners in the science classroom. Dekkers (2004:14) describes his teaching of the concepts of the "nature of science" (discussed in Section 4.3.4) as a "development" or as a "rather gradual process of piecemeal and ongoing change".

5.3.2.3 Adaptation of texts

The adaptation of science texts is a strategy discussed by Von Glasersfeld (1995:140). Gardner (1972 in Block 2002:29-30) found that many words used in textbooks were not accessible to learners. Wood and Wood (1988 in Block 2002:29-30) suggest that textbooks are at least partly to blame for difficulties in learning science, while Lemke (1982) comments that science textbooks are "ponderous".

Taking the above unstructured and structured views into account, the following section discusses possible suggestions to follow in order to assist learners in understanding the vocabulary used in their lectures and textbooks more clearly.

5.3.3 Suggestions to solve the vocabulary problems of learners

Several groups of people appear to be responsible for the problem that exists with the learners' understanding of essential scientific vocabulary. Firstly, teaching staff do not realise that the message is not adequately structured. Secondly, institutions do not make room for correcting the error in the course itself. Thirdly, teaching faculties do not include language training in the training of science teachers. Lastly, the learners themselves do not read extensively and may not be inquisitive; if a word does not seem to make sense, they merely accept what the lecturers say at "face value", which for the student may be very different from what the "face value" may be for the lecturer. One could blame the education system as a whole for the poor language skills with which learners emerge from Grade 12, but even being able to place blame accurately would not in itself solve the problem. Some suggestions involving various role-players in or elements of the education field follow.

5.3.3.1 Teacher training institutions

Teachers and lecturers in training must learn about language issues while studying their science and teaching courses. Language and terminology issues need to be addressed in the syllabus and need to be tested along with the core science courses. Many would argue that science teachers do not necessarily have the skills, interest or aptitude required for language teaching and that there is no space in the curriculum for extra activities. However, space should be created in the curriculum to teach science teachers and lecturers about the language problems their learners will face in the classroom. There seems to be little point in training a teacher for four years and then leaving out such an essential part as being able to structure a message which will be able to move from sender to receiver with as little distortion as possible. An even more important point is that many lecturers at higher education institutions have no training as teachers and therefore in-service training in the form of staff development workshops is important for lecturing staff.

5.3.3.2 Lecturers

It is clear from the study that the main focus of remediation is the learner, while the lecturer is the party who is best placed to identify problems and suggest solutions. Lecturers should be working with all the role-players (the learners, the department and faculty and with other lecturers) on various aspects of learners' education. The lecturer is primarily responsible for selecting the coursework and can structure or restructure material to ameliorate the vocabulary problem. The lecturer is in the best position to develop and present short vocabulary courses, but without support from the department or faculty such courses may not be developed and presented.

In an effort not to add more to the formal lecture load, lecturers could include explanations of basic vocabulary in the formal academic workload. In addition to this strategy, tutors or learning facilitators could explicitly deal with the terminology commonly used in the subject. English or academic skills departments could also introduce a module on the academic use of lay vocabulary.

Lecturers would do well to reflect upon the following checklist for teachers relating to the presentation of science terms compiled by Wandersee (1988:99):

- Are you analytical in selecting the science terms you expect your students to master?
- Do you omit some textbook terms and also add some that aren't in your textbook?
- Do you explain the origin and meaning of each term you require students to learn?
- Do you point out difficulties students may encounter in learning a new term?
- Do you pronounce the term properly and then have students say it aloud?
- Do you attempt to connect the term to students' existing knowledge?
- Do you offer laboratory or field experiences to anchor the term to real objects or events?
- Do you "model" the use of a new term and expect your students to use it in speaking or writing?
- Do you show your students the value of learning new science terms?

In addition to asking the above questions, Laufer and Hulstin (2001:13) present several tasks which lecturers could set for their learners to improve vocabulary understanding. The tasks they suggest include selecting the meaning from several options, looking up the meaning in a dictionary and using the words in original sentences and compositions.

5.3.3.3 Curricula

Science language and terminology should be deliberately taught as a part of the curriculum. This view supports that of Cervellati *et al.* (1984:269) and Gonzales (1981:20). Dekkers (2004:2) states that aspects of the "nature of science", and presumably also the meaning of the terms "science" and "scientific", should be taught explicitly.

Wood (1994:169-170) suggests the establishment of "a cognitive meta-curriculum" or bridging programme before the commencement of the formal degree or diploma programme. Many higher education institutions such as the University of Pretoria, WITS, the University of the North and MEDUNSA already have courses such as this in place, and the curricula of these courses is a possible ideal place for certain language proficiency exercises to be done.

5.3.3.4 Materials used in education

Textbook and materials developers should be acutely aware of how vocabulary is used in their materials and should go to some trouble to point out differences between the lay meaning of words and the specialised meanings of words. A biology textbook could give a brief overview as to how a specific word, such as "cell", is used in different fields, such as Physics, Criminology, Information Technology and Biology. This would alert the learners to the principle that the same word can be used with different specialised meanings in different courses.

Most text-books have glossaries and the learners should be explicitly instructed to study the glossary for certain sections of the work. Lecturers can also prescribe or at least direct their learners to examine specialist dictionaries such as *A mathematical dictionary for schools* (Bolt & Hobbs, 1998), which is a comprehensive but simply written dictionary for high-school children, foundation year learners and under-graduates in Mathematics.

5.3.3.5 Researchers

Researchers in language and science departments should attempt to convince their colleagues of the necessity to address vocabulary in the science classroom. Results of studies such as this one should be presented at departmental seminars and at conferences to alert lecturers to the danger of making assumptions regarding their learners' vocabulary skills.

5.3.3.6 Learners

The relatively high percentage of learners admitting to not fully understanding the meaning of words halfway through the academic year may be attributed to the fact that the learners may simply never have thought about their own understanding before being asked. It might well be that when they were asked about their understanding, many learners realised for the first time that they may not have as comprehensive an understanding as they would like of a specific word. It may be that because learners were not aware of their inadequate knowledge, they did not rectify the situation.

To benefit the learners, a test or exercise of the type used in this study could be given at the beginning of the academic year so that learners might be alerted to the fact that their knowledge level is not ideal.

Learners should also be encouraged to take responsibility for understanding their lectures, hand-outs or textbooks and should be pointed to dictionaries and the glossaries in the textbooks, even if they think they understand the words. The internet contains numerous Physics dictionary websites such as *Let's clean up our Physics language* (Simanek 2002), *Physics terms, words and jargon* (Anderson 2004) and *Your dictionary,* which contains links to hundreds of specialised dictionaries. Most learners have access to the internet and should be directed to relevant websites with specific vocabulary tasks to complete.

In conclusion, Science vocabulary teaching is not the sole responsibility of the science teacher. Language practitioners, academic development specialists, heads of department and curricula planners all need to take cognisance of the inadequate language knowledge of learners and should develop strategies to assist learners to acknowledge and to rectify this situation. At the same time, lecturers should take heart — time and immersion in the language of a subject does lead to increased awareness and more sophisticated use of the terminology of that subject.

5.4 Limitations and suggestions for further research

The main study was limited to a relatively small group of learners at one institution and a limited number (16) of words.

The study could be repeated for larger samples using different words. The number of lecturers who participated in this study was extremely limited (only four) due to the teaching load of the lecturers. Due to the small number of lecturers who participated in the study and the subjective responses elicited from the lecturers, the results of parts of this study were largely influenced by the lecturers' subjective perceptions. Further studies could be undertaken into lecturers' perceptions of learners' knowledge and skills in various other courses such as Chemistry, Biology, Geography and Mathematics.

Another area of research that could be pursued is the different ways that Physics and Chemistry lecturers use the term "mass", a term that was excluded from this study because Physics and Chemistry lecturers involved in the development of the questionnaires could not agree on the meaning of the term.

5.5 Conclusion

John Locke (1690 in Von Glasersfeld 1995:89) stated that "understanding, like the eye, whilst it makes us see and perceive all other things, takes no notice of itself; and it requires art and pains to set it at a distance and make it its own subject". The same can be said for the use of language, particularly for the "common" terms that are used in the science classroom. For many lecturers, some of the common terms used in the classroom need no mention, no special explanation, no introduction. Yet this research has shown that in many cases, it is these very terms that may lead to misunderstanding. The terms themselves are not difficult to explain, they just are never or rarely explained.

To summarise the above suggestions it would be useful to quote Eggen and Kauchak (1997:35) who ask: "What can teachers do when students come to them lacking the necessary experience to make the topics they're teaching meaningful?" Their answer is simple: "Provide it for them."

BIBLIOGRAPHY

Abraham, MR, Grzybowski, EB & Renner, JW. 1992. Understandings and misunderstandings of eighth graders of five Chemistry concepts found in textbooks. *Journal of Research in Science Teaching*, 29(2): 105-120.

Amos, L & Fischer, S. 1998. Understanding and responding to student learning difficulties within the higher education context: a theoretical foundation for developing academic literacy. *South African Journal of Higher Education*, 12(2): 17-23.

Anderson, J. 2004. *Physics terms, words and jargon.* [http://physics.about.com/cs/glossary/a/glossary.htm]. 15 November 2004.

Ayer, AJ. 1983. *Language, truth and logic*. Harmondsworth: Penguin.

Barthes, R. 1984a. *Elements of semiology.* New York: Hill and Wang.

Barthes, R. 1984b. *Image, music, text.* New York: Hill and Wang.

Berlo, DK. 1960. *The process of communication. An introduction to theory and practice.* New York: Holt, Rinehart and Winston.

Bird, E & Welford, G. 1995. The effect of language on the performance of second-language students in science examinations. *International Journal of Science education*, 17(3): 389-397.

Blackburn, S. 1975. *Meaning, reference and necessity.* Cambridge: Cambridge University Press.

Block, E. 2002. First-year university students' understanding of aspects of language in a selected geography topic. Unpublished Master's research report, University of the Witwatersrand, Johannesburg.

Bolt, B & Hobbs, D. 1998. *A mathematical dictionary for schools*. Cambridge: Cambridge University Press.

BouJaoude, SB. 1992. The relationship between students' learning strategies and the change in their misunderstandings during a high school Chemistry course. *Journal of Research in Science Teaching,* 29(7): 687-699.

Brock-Utne, B & Holmarsdottir, HB. 1993. Language policies and practices in Tanzania and South Africa: problems and challenges. *International Journal of Educational Development,* 24: 67-83.

Bronowski, J. 1978. *The origins of knowledge and imagination*. London: Yale University Press.

Bryson, B. 2003. *A short history of nearly everything.* Parktown: Random House.

Bulman, L. 1986. *Teaching language and study skills in secondary science*. London: Heinemann.

Carrell, PL, Devine, P & Eskey, DE (eds). 1988. *Interactive approaches to second language reading*. Cambridge: Cambridge University Press

Cervellati, R, Concialini, V, Innorta, G & Perugini, D. 1984. Chemical knowledge of students entering a first-year Chemistry course in Italy. *European Journal of Science education*, 6(3): 263-270.

Chandler, D. 2004. *Transmission model of communication.* 8 March 2004. http://www.aber.ac.uk/media/Documents/short/trans.html. 3 April 2004.

Chomsky, N. 1986. *Knowledge of language.* New York: Praeger.

Clarck, RJ. 1972. *Bertrand Russell's philosophy of language.* The Hague: Martinus Nijhoff.

Cobern, WW (ed.). 1998. *Socio-cultural perspectives on Science education.* London: Kluwer Academic.

Cobern, WW. 1991. *World view theory and Science education research.* NARST monograph 3. Manhattan: National Association for Research in Science Teaching.

Cohen, L, Manion, L & Morrison, K. 2002. *Research methods in Education*. Fifth edition. London: RoutledgeFalmer.

Crystal, D. 1988. *The English language*. Harmondsworth: Penguin

Cummins, J. 2000. *Language, power and pedagogy. Bilingual children in the crossfire.* Clevedon: Multilingual Matters.

Dekkers, P. 2004. Teaching teachers NOS. Practical examples and classroom experiences. Unpublished paper from seminar presented at the University of Pretoria, November, 2004.

De Saussure, F. 1959. *Course on general linguistics* (translation by W Baskin) New York: Philosophical library.

Dembo, MH. 1988. *Applying educational psychology.* Fifth edition. New York: London.

Descartes, R. 1984. *A discourse on method*. London: Dent.

Descartes, R. 1985. *Discourse on method and The Meditations.* Harmondsworth: Penguin.

Ditcher, A. 1999. Factors influencing university students' academic success: What do students and academics think? *HERDSA conference proceedings,* Melbourne: HERDSA.

Donaldson, EL & Kurtz, SM. 1997. Applications of an interpersonal communication model to educational environments. *Canadian Journal of Communications,* 22:1. [http://info.wlu.ca/~wwwpress/jrls/cjc/BackIssues/22.1/donalds.html]. 12 November 2004.

Donovan, MP. 1997. The vocabulary of Biology and the problem of semantics. *Journal of College Science Teaching,* 26(6): 381-382.

Duncan, DB. 1955. Multiple range and multiple *F* tests. *Biometrics,* 11:1-42

Dykstra, DI, Boyle, CF & Monarch, IA. 1992. Studying conceptual change in learning Physics. *Science education*, 76(6): 615-652.

Eggen, P & Kauchak, D. 1997. *Educational Psychology.* Third edition. Upper Saddle River: Prentice Hall.

Egli, U, Pause, P, Schwarze, C, Von Stechow, A & Wienold, G (eds). 1984. *Lexical knowledge in the organisation of language.* Amsterdam: John Benjamins.

Eikmeyer, H & Rieser, H. 1981. *Words, worlds and contexts. New approaches in words semantics.* New York: Walter de Gruyter.

Einstein, A. 1954. *Physics and reality. Ideas and opinions*. New York: Bonanza.

Eiselin, R & Geyser, H. 2003. Factors distinguishing between achievers and at risk students: a qualitative and quantitative synthesis. *South African Journal of Higher Education*, 17(2): 118-130.

Elam, K. 1980. *The semiotics of theatre and drama*. London: Methuen.

Fiske, J. 1989. Semiotics: Its contribution to the study of intercultural communication. *Perspectives in Communication Theory and Research*, no number 831-837.

Flagg, V. 1999. Breaking the deal: an investigation of the impact of an integrative teaching approach on the perceived fragmentation of knowledge reported to accompany framework units. *HERDSA conference proceedings.* Melbourne: HERDSA.

Flew, A. 1979. *A dictionary of philosophy.* London: Pan.

Frank, M. 1989. *What is Neostructuralism?* Minneapolis: University of Minnesota Press.

Gardener, H.1972. *The quest for mind. Piaget, Levi-Strauss and the structuralist movement.* London: Coventure.

Gladkij, AV & Mel'cuk, IA. 1983. *Elements of mathematical linguistics.* Berlin: Mouton.

Gadsby, A (ed.). 1995. *Longman dictionary of contemporary English. The complete guide to written and spoken English*. Harlow: Pearson

Gonzales, PC. 1981. Teaching Science to ESL students. *The Science Teacher,* January:19-21.

Gorodetsky, M & Gussarsky, E. 1986. Misconceptions of the chemical equilibrium concept as revealed by different evaluation methods. *European Journal of Science education,* 8(4): 427-441.

Griffiths, AK & Preston, KR. 1992. Grade 12 students' misconceptions relating to fundamental characteristics of atoms and molecules. *Journal of Research in Science Teaching,* 29(6): 611-628.

Guttenplan, S. 1975. *Mind and language.* Oxford: Clarendon Press.

Hart, C. 2002. If the sun burns you is that a force? Some definitional prerequisites for understanding Newton's laws. *Physics Education,* 37(3): 234-238.

Hawkes, T. 1985. *Structuralism and semiotics.* London: Methuen.

Hermans, JM & Kempen, JG. 1993. *The dialogical self.* London: Academic Press.

Jackendoff, R. 1986. *Semantics and cognition.* Cambridge, Massachusetts: MIT Press.

Jackson, H & Ze Amvela, E. 2000. *Words, meaning and vocabulary.* London: Cassell.

Jackson, H. 1996. *Words and their meaning*. New York: Addison Wesley Longman.

Jacobs, G. 1989. Word usage misconceptions among first-year university Physics students. *International Journal for Science education,*11(4): 395-399.

Johnson, RB & Christenson, L. 2004. Educational research. Quantitative, qualitative and mixed approaches. New York: Longman

Kirschenbaum, H & Henderson, VL (eds). 1989. *Carl Rogers: dialogues.* Boston: Howard Mifflin.

Laufer, B & Hulstin, J. 2001. Incidental vocabulary acquisition in a second language. The construct of task-induced involvement. *Applied Linguistics*, 22(1):1-26

Lave, J. 1997. The culture of acquisition and the practice of understanding. In D Kirshner & JA Whitson (eds), *Situated cognition: social, semiotic and psychological perspectives*. Mahwah: Lawrence Erlbaum: 17-36.

Le Guin, U. 1992. *Dancing at the edge of the world*. London: Paladin.

Lemke, J. 1982. Talking Physics. *Physics Education,* 17: 263-267.

Lewis, CS. 1990. *Studies in words.* Cambridge: Cambridge University Press.

Lipson, A. 1992. The confused student in Introductory Science. *College Teaching,* 40(3): 91-95.

Lyons, J. 1977. *Chomsky*. London: Fontana.

Manchester, M. 1985. *The philosophical foundations of Humboldt's linguistic doctrines.* Amsterdam: John Benjamins.

Mbuli, M. 2004, 20 February. [Mbuli.M@doe.gov.za] "Research question". Private e-mail message to K Naudé [karen.naude@up.ac.za].

McKenna, S. 2004. Lecturers' discourses about the interplay between language and learning. *South African Journal of Higher Education*. 18(2): 278-287

Mc Millan, JH & Schumacher, S. 1997. *Research in education: A conceptual introduction.* Harlow: Longman.

McCloskey, M. 2002. "Tell it often - tell it well." Chapter 17: an interpersonal communication model. 17 May 2002. [http://www.greatcom.org/resources/tell_it_often_tell_it_well/chap17/default.htm]. 4 March 2004.

Meyer, JHF & Boulton-Lewis, GM. (1999) On the operationalisation of conceptions of learning in higher education and their association with students' knowledge and experiences of their learning. In *Higher Education Research and Development Society of Australasia.* [http://www.herdsa.org.au/meyer183.htm]. 18 July 2001.

Minstrel, J. 1992. Facets of students' knowledge and relevant instruction. In R Durr, F Goldberg & H Niedderer (eds), *Research in Physics Learning – theoretical issues and empirical studies,* Kiel: IPM: 110-128.

Moji, NC. 1998. Investigation of conceptual and language difficulties affecting the understanding of several Mechanics concepts among some African teachers and students. Unpublished PhD dissertation, University of Natal, Pietermaritzburg.

Moji, NC. 2004. Personal interview. Lecturer in Physics, University of Pretoria.

Mouton, J & Marais, HC. 1991. *Basic concepts in the methodology of the social sciences.* Pretoria: Human Sciences Research Council.

Mouton, J. 2001. *How to succeed at your Master's and Doctoral studies.* Pretoria: Van Schaik.

Nantunewicz, MAT. 2000. "Origin and foundation myths of Rome as presented in Vergil, Ovid and Livy". *Myth Unit 10.* n.d. [http://www.uh.edu/hti/cu/2000/v05/04.htm]. 18 October 2004.

Neuman, WL. 2003. *Social research methods. Qualitative and quantitative approaches.* Fifth edition. New York: Allyn and Bacon.

Newton, I. 1687. *Philosophiae Naturalis Principia Mathematica.* Translated by A Motte. 1729. 26 July 1998. n.d. [http://members.tripod.com/~gravitee/definitions.htm]. 11 November 2004.

O'Regan, K. 1999. *Mathematically speaking: The importance of language in the learning of Mathematics.* Proceedings of the HERDSA Conference. Melbourne.

O'Toole, M. 1996. Science, schools, children and books: exploring the classroom interface between science and language. *Studies in science education,* 28: 113-143

Orr, MH & Schutte, CJH. 1992. *The language of science.* Durban: Butterworths.

Pare, PT. 2004, 18 October. [phillip.pare@up.ac.za] "Force in many languages". Private e-mail message to K Naudé [karen.naude@up.ac.za.].

Piaget, J. 1968. *Structuralism.* London: Routledge and Kegan Paul.

Pinto, D (ed.). 2001. Proceedings of the Indaba of Science, Engineering and Technology foundation programmes. Johannesburg: College of Science, University of the Witwatersrand.

Pope, ML & Gilbert, JK. 1983. Explanation and metaphor: some empirical questions in Science education. *European Journal of Science Education*, 5(3): 249-261.

Popper, K. 1968. *Conjectures and refutations: the growth of scientific knowledge.* New York: Harper Torchbooks.

Reiss, S. 1953. *The universe of meaning.* New York: Philosophical Library.

Rieber, RW, Aron, A & Carton, S (eds). 1987. *The collected works of L.S.Vygotsky*. London: Plenum.

Sager, J. 1990. *A practical course in terminology processing.* Amsterdam: John Benjamins.

SASS Institute. 1999. *SASS/STAT users guide.* Version 8. Volume 2. Cary, North Carolina: SASS Institute.

Schunk, D. 2000. *Learning theories. An educational perspective.* Upper Saddle River: Prentice Hall.

Seliger, HW & Shohamy, E. 1989. *Second language research methods.* Oxford: Oxford University Press.

Shannon, C & Weaver, W. 1962. *The mathematical theory of communication*. Urbana: University of Illinois Press.

Shoebottom, P. 2001. Second language acquisition. *The language learning theories of Professor J. Cummins.* 8 August 2003. [http://esl.fis.edu/teachers/support/cummin.htm]. 26 October 2004.

Simanek, DE. 2002. *Let's clean up our Physics language.* [http://www.lhup.edu/~dsimanek/scenario/physlang.htm]. 15 November 2004.

Slavin, RE. 2003. *Educational Psychology. Theory and practice.* Seventh edition. Boston: Allyn and Bacon.

Smock, CD & Von Glasersfeld, E. (eds). 1974. *Epistemology and education: the implications of radical constructivism for knowledge acquisition.* (Report #14). Athens, Georgia: Follow Through Publications

Sutton, CR (ed.).1981. *Communicating in the classroom : a guide for subject teachers on the more effective use of reading, writing and talking*. London: Hodder & Stoughton

Sutton, CR. 1992. *Words, Science and learning*. Buckingham: Open University Press.

Struwig, FW & Stead, GB. 2001. *Planning, designing and reporting research.* Pinelands, Cape Town: Pearson

Tapper, J. 2000. *Partnerships in the development of students' communication skills.* [http://www.herdsa.org.au/branches/vic/Cornerstones/abstracts/tapper.html]. 18 July 2001.

Tondl, L. 1966. *Problems of semantics. A contribution to the analysis of the language of Science.* Dordrecht: D Reidel.

Turabin, KL. 1996. *A manual for writers of term papers, theses and dissertations.* Sixth edition. Chicago: University of Chicago Press.

Underwood, M. 2003. Introductory models and basic concepts. [http://www.cultsock.ndirect.co.uk/MUHome/cshtml/introductory/trancrit.html]. 4 March 2004.

Urmson, JO (ed.). 1985. *The concise encyclopaedia of western philosophy and philosophers*. Bergvlei: Century Hutchinson.

Vaccarino, G. 1981. *Analysis of meanings*. Rome: Armando.

Vaccarino, G. 1988. *Science and constructivist Semantics*. Milan: CLUP.

Van Schoor, M. 1986. *What is communication?* Pretoria: JL van Schaik.

Von Glasersfeld, E. 1989. Constructivism in education. In T Husen & TN Postlewhaite (eds), *The international encyclopaedia of education*, Supplemental volume 1, Pergamon Press: 162-163.

Von Glasersfeld, E. 1995. Radical constructivism. *A way of knowing and learning*. London: Taylor & Francis.

Vygotsky, LS. 1962. *Thought and language*. Cambridge, Massachusetts: MIT Press.

Walker, G. 1996. What students think they know. *New Academic,* 5(2): 5-7.

Wandersee, JH. 1988. The terminology problem in biology education: a reconnaissance. *The American Biology teacher,* 50(2): 97-100.

Wandersee, JH. 1992. The historicality of cognition: implications for Science education research. *Journal of Research in Science Teaching,* 29(4): 423-434.

Westbrook, SL & Marek, EA. 1991. A cross-age study of student understanding of the concept of diffusion. *Journal of Research in Science Teaching*, 28(8): 649-660.

Whorf, BL. 1956. *Language, thought and reality.* Cambridge, Massachusetts: MIT Press.

Wierzbicka, A. 1980. *Lingua Mentalis. The semantics of natural language.* Sydney: Academic Press.

Wood, T. 1994. Semantics and the learners' interpretation of texts. *Conference proceedings, 1994: challenging educational policies and practices.* Durban: The South African Association for Academic Development.

Woodward-Kron, R. 1999. Learning the discourse of a discipline: The nature of the apprenticeship. Proceedings of the HERDSA conference. Melbourne.

Your dictionary.com. http://www.yourdictionary.com/diction5a.html. 15 November 2004

Zeegers, P. 1999. Students' learning in Science: a longitudinal study using the Biggs SPQ. Proceedings of the HERDSA conference. Melbourne.

Zeidler, D L & Lederman, N G. 1989. The effect of teachers language on students' conceptions of the nature of science. *Journal of Research in Science Teaching,* 26(9): 771-783.

Zeilik, M, Schau, C & Mattern, N. 1998. Misconceptions and their change in university-level Astronomy courses. *The Physics Teacher,* 36(Feb): 104-107.

APPENDICES

Appendix A: Pinto (2001): Summary of language problems brought up at the first Science Indaba

Appendix B: Pinto (2001): Perceived barriers to communication

Appendix C: Moji (1998:258): Interview with "Teacher Paul"

Appendix D: Moji (1998:260): Interview with "M"

Appendix E: Main study: Science vocabulary questionnaire: Section A (tests students' self-awareness of the meanings of the terms)

Appendix F: Main study: Science vocabulary questionnaire: Section B (tests students' actual knowledge of the meanings of the terms)

Appendix G: Main study: Science vocabulary questionnaire: Section C (open-ended questionnaire to test students' overall knowledge of the meanings of the terms)

Appendix H: Main study: Science vocabulary questionnaire: Section D (determines what lecturers think learners know)

Appendix A: Pinto (2001): Summary of language problems brought up at the first Science Indaba

- Most concepts are secondary concepts, i.e. they are arrived at through language, not through immediate experience.
- New meanings for familiar words, e.g. table, periodic.
- Less contextual clues than school stories / narratives.
- Understanding of demonstrations / demonstrators.
- Use of a variety of tenses for report writing, writing up experiments, academic essays, etc.
- Use of nominalizations and passive voice as characteristic of scientific text.
- Using an academic register for essay writing.
- Listening reading for specific information, students are often distracted by minor details and miss main points.
- Following instructions – oral and written.
- Using graphs, charts and tables for sourcing information.
- Formulating questions / asking questions.
- Understanding of cultural differences and how these influence the production and interpretation of language.
- Organising information in a logical manner, using cohesive devices to signal transitions in text.
- Aiming for coherence.
- Integrating quotes.
- Topic control in written text.
- Awareness of target audience for spoken and written communication.

Appendix B: Pinto (2001): Perceived barriers to communication

The frequency of responses shown in brackets, where N=106:

- Vocabulary / terminology (58)
- Lack of English proficiency (16)
- Answering questions (14)
- Language register (10)
- Following instructions (7)
- Pronunciation of terms (7)
- Accent (6)
- Writing (6)
- Figures in Science, use of other languages, asking questions, grammar (3 each)
- Speed of talking by lecturers (2)
- Use of English as language identity (1)

Appendix C: Moji (1998:258): Interview with "Teacher Paul"

("Teacher Paul" is a subject advisor in the Free State highlands region. He taught Physical Science for sixteen years in senior primary school.)

Moji: What would we call kinetic energy in your language?

Paul: Ke matla … a ntho tse tsamayang. [It is "matla" of the moving objects.]

Moji: OK, you say force and momentum; what are force and momentum in your language?

Paul: Force ke Sesetho, e ka re e tla nne e be matla he. [Force in Sesotho, it will probably still be "matla" then.]

Moji: What is momentum in your language?

Paul: E nste e le matla le yona. [It is "matla" too.]

Moji: You must note now, you said energy is "matla", you say force is "matla" and now you want to say momentum is "matla" as well.

Paul: E jwaloaha acceleration e le lebelo, velocity e le lebelo le speed e le lebelo. [It is just as acceleration is "lebelo", velocity is "lebelo" and speed is "lebelo".]

Moji: All right, what is the connection between power and energy, what is power in your language?

Paul: Ke matla. [It is "matla".]

Moji: So we are counting four? Energy, force, momentum and power! Ke matla Kaofel [All are "matla"?]

Paul: Hantle! Ke matla kaofelo. [Exactly! All are "matlas".]

Appendix D: Moji (1998:260): Interview with "M"

(M is an Indian Master's student in Physics whose home language is English.)

Moji: If you throw a ball, what do you do if you want it to go much higher?

Student: I would give it more force.

Moji: Give it more force?

Student: Yes, more power to make it go higher.

Moji: More power?

(He noted that I was investigating something, he remembered that I was working on the "amandla" issue.)

Student: Ugh man, you give it more energy! Give it more amandla, it will go higher.

(Moji 1998:260)

Appendix E: Main study: Science vocabulary questionnaire: Section A

We want to find out how well our students understand basic terms used in Physics. Students who have a vague understanding about the meanings of common Physics words used daily in the classroom may have difficulty in understanding more complex concepts that are built upon an understanding of these words.

This questionnaire is part of an attempt to find out which basic terms our students are having difficulty with, so that we can give you appropriate feedback and helpful tuition.

The information in this questionnaire is to be used for research purposes only, and will not influence your mark **in any way**. Your answers will be treated confidentially.

You are asked to co-operate by answering this questionnaire (Section A) and the one which follows (Section B). It is important that you answer as carefully and as truthfully as possible. Please respond to **every** item.

Instructions for completing the answer sheet:

- Use Side 1 of the answer sheet.
- Please fill in your student number, surname, initials, date, degree course and subject code in the spaces provided.
- Please mark each response clearly with a pencil.
- Colour in the full circle.
- Only one option per item is allowed.
- Please answer every item.

please turn over

Instructions for answering the questions:

- Read each of the sentences below.
- Carefully consider the meaning of the word in *italics*.
- Do you understand the meaning of the word? What is your level of understanding of the word in the sentence? Would you say you have complete, partial or no understanding of the word?
- Indicate your response by marking the appropriate space on the answer sheet depending on your level of understanding.

A = Yes (I understand the meaning of the word in this context.)

B = Some (I have some idea of the meaning of this word in this context.)

C = No (I do not understand the meaning of this word in this context.)

Start answering at number 1 on the answer sheet.

1	Light is a natural ***phenomenon.***
2	During the experiment, the ***observations*** were made independently.
3	The volume of water in a tank is a ***function*** of the height of the tank.
4	Close to the North Pole the angle of ***deviation*** of a compass needle is large.
5	Surface A is ***normal*** to surface B.
6	The ***density*** of material A is greater than that of material B.
7	Collisions between molecules in a gas occur at ***random***.
8	***Pressure*** in a liquid is determined by the depth below the surface of the liquid.
9	The ***distribution*** of the noise was the same throughout the room.
10	The area of a triangle is ***proportional*** to its height and proportional to its base.
11	The ***acceleration*** of a free-falling object is constant.
12	The ***frequency*** of the vibration of a spring depends on the stiffness of the spring.
13	By ***convention*** we draw vectors so that they point in the direction of the force applied.
14	A ***scientific*** inquiry was conducted into the accident.
15	The researcher has formulated a ***model*** about the behaviour of gases.
16	The ***error*** in the measurement of the table was large.

Appendix F: Main study: Science vocabulary questionnaire: Section B

You now have the opportunity to explore your understanding of the vocabulary used in the sentences in Section A.

Instructions:

For every numbered option please indicate whether it means the same as, or whether it has a different meaning from **your understanding** of the word, within the context of this sentence.

Indicate your response by marking:

A = Yes, this is the meaning of the word in this context.

B = No, this is not the meaning of the word in this context.

Any number of the possible options may be correct or incorrect. In some questions all items may be correct or incorrect. Treat each possible 'meaning' on its own merits. It is very important that you respond to **every** item. Continue answering at number 17 on the answer sheet.

Light is a natural *phenomenon*.	**No**	**phenomenon**
Possible meanings:	17	happening
	18	magical event
	19	occurrence
During the experiment, the *observations* were made independently.		**observations**
Possible meanings:	20	comment
	21	visual experience
	22	findings
The volume of water in a tank is a *function* of the height of the tank.		**function**
Possible meanings:	23	calculation
	24	mathematical relation
	25	sum

Close to the North Pole the angle of *deviation* of a compass needle is large.		**deviation**
Possible meanings:	26	error
	27	deflection
	28	change in direction
Surface A is *normal* to surface B.		**normal**
Possible meanings:	29	the same
	30	at right angles
	31	perpendicular
The *density* of material A is greater than that of material B.		**density**
Possible meanings:	32	heaviness
	33	thickness
	34	mass per volume
Collisions between molecules in a gas occur at *random*.		**random**
	35	orderless
	36	by chance
	37	unpredictable
***Pressure* in a liquid is determined by the depth below the surface of the liquid.**		**pressure**
Possible meanings:	38	burden
	39	force per area
	40	intensity

The *distribution* of the noise was the same throughout the room.		**distribution**
Possible meanings:	41	spread
	42	sound
	43	circulation
The area of a triangle is *proportional* to its height and proportional to its base.		**proportional**
Possible meanings:	44	relative to
	45	equal to
	46	depends on
The *acceleration* of a free-falling object is constant.		**acceleration**
Possible meanings:	47	change in velocity
	48	forward movement
	49	speed
The *frequency* of the vibration of a spring depends on the stiffness of the spring.		**frequency**
Possible meanings:	50	frequently
	51	regularity
	52	repetitions per unit of time

By *convention* we draw vectors so that they point in the direction of the force applied.		**convention**
Possible meanings:	53	agreement
	54	conference
	55	discussion
A *scientific* inquiry was conducted into the accident.		**scientific**
Possible meanings:	56	objective
	57	systematic
	58	experimental
The researcher has formulated a *model* about the behav-iour of gases.		**model**
Possible meanings:	59	explanation
	60	idea of how things work
	61	example
The *error* in the measurement of the table was large.		**error**
Possible meanings:	62	uncertainty
	63	wrong judgment
	64	miscalculation

Please indicate whether English is your home language at number 65.

A = Yes, English is my home language.

B = No, English is not my home language.

Thank you for your participation in this study.

Appendix G: Main study: Science vocabulary questionnaire: Section C

Clearly explain the meaning of the italicized word in each sentence.

1	Light is a natural ***phenomenon.***
2	During the experiment, the ***observations*** were made independently.
3	The volume of water in a tank is a ***function*** of the height of the tank.

4	Close to the North Pole the angle of ***deviation*** of a compass needle is large.
5	Surface A is ***normal*** to surface B.
6	The ***density*** of material A is greater than that of material B.
7	Collisions between molecules in a gas occur at ***random***.

8	***Pressure*** in a liquid is determined by the depth below the surface of the liquid.
9	The ***distribution*** of the noise was the same throughout the room.
10	The area of a triangle is ***proportional*** to its height and proportional to its base.
11	The ***acceleration*** of a free-falling object is constant.
12	The ***frequency*** of the vibration of a spring depends on the stiffness of the spring.

13	By ***convention*** we draw vectors so that they point in the direction of the force applied.
14	A ***scientific*** inquiry was conducted into the accident.
15	The researcher has formulated a ***model*** about the behaviour of gases.
16	The ***error*** in the measurement of the table was large.

Appendix H: Main study: Science vocabulary questionnaire: Section D

Dear lecturer,

This questionnaire forms part of a study examining students' understanding of certain words used commonly in the Physics classroom. We are asking students to say whether they think they understand the meaning of a word in the context of a sentence. We are then testing to determine whether they actually understand the meaning of that word.

Would you please write down what percentage of your students in the UPFY Physics 2002 cohort you think accurately understand the meaning of the italicized words in the given sentences.

	Sentence	Percentage of students who you think understand the meaning of the italicized word in this sentence.
1	Light is a natural ***phenomenon.***	
2	During the experiment, the ***observations*** were made independently.	
3	The volume of water in a tank is a ***function*** of the height of the tank.	
4	Close to the North Pole the angle of ***deviation*** of a compass needle is large.	
5	Surface A is ***normal*** to surface B.	
6	The ***density*** of material A is greater than that of material B.	
7	Collisions between molecules in a gas occur at ***random***.	
8	***Pressure*** in a liquid is determined by the depth below the surface of the liquid.	
9	The ***distribution*** of the noise was the same throughout the room.	
10	The area of a triangle is ***proportional*** to its height and proportional to its base.	
11	The ***acceleration*** of a free-falling object is constant.	
12	The ***frequency*** of the vibration of a spring depends on the stiffness of the spring.	
13	By ***convention*** we draw vectors so that they point in the direction of the force applied.	
14	A ***scientific*** inquiry was conducted into the accident.	
15	The researcher has formulated a ***model*** about the behaviour of gases.	
16	The ***error*** in the measurement of the table was large.	